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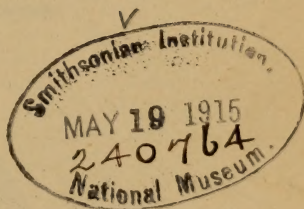
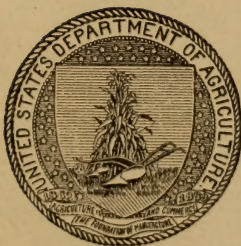
BUREAU OF ENTOMOLOGY—BULLETIN No. 116. —119. 1912-13

L. O. HOWARD, Entomologist and Chief of Bureau.

PAPERS ON DECIDUOUS FRUIT INSECTS
AND INSECTICIDES.

CONTENTS AND INDEX.

ISSUED JANUARY 18, 1915.



WASHINGTON:
GOVERNMENT PRINTING OFFICE.
1915.

U. S. DEPARTMENT OF AGRICULTURE,
BUREAU OF ENTOMOLOGY—BULLETIN No. 116.

L. O. HOWARD, Entomologist and Chief of Bureau.

PAPERS ON DECIDUOUS FRUIT INSECTS
AND INSECTICIDES.

I. SPRAYING EXPERIMENTS AGAINST THE GRAPE LEAFHOPPER
IN THE LAKE ERIE VALLEY IN 1911.

By FRED JOHNSON, *Agent and Expert.*

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By E. W. SCOTT and E. H. SIEGLER, *Entomological Assistants,*
Deciduous Fruit Insect Investigations.

V. THE FRUIT-TREE LEAF-ROLLER.

By JOHN B. GILL, *Entomological Assistant.*



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GOVERNMENT PRINTING OFFICE.

1915.

BUREAU OF ENTOMOLOGY.

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DECIDUOUS FRUIT INSECT INVESTIGATIONS.

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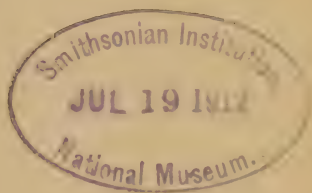
PAPERS ON DECIDUOUS FRUIT INSECTS
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BY

FRED JOHNSON,
Agent and Expert.

ISSUED JULY 15, 1912.



WASHINGTON:
GOVERNMENT PRINTING OFFICE.

1912.

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PAPERS ON DECIDUOUS FRUIT INSECTS AND INSECTICIDES.

SPRAYING EXPERIMENTS AGAINST THE GRAPE LEAFHOPPER IN THE LAKE ERIE VALLEY IN 1911.

By FRED JOHNSON,
Agent and Expert.

INTRODUCTION.

An insect pest of the grapevine which has increased in abundance and destructiveness in the vineyards of the Lake Erie Valley during the past few years is the grape leafhopper, *Typhlocyba comes* Say (see fig. 1). Preliminary spraying experiments were undertaken against this pest at North East, Pa., by the Bureau of Entomology in 1910. Results of the field work undertaken during that season are presented in Bulletin No. 97, Part I, of the Bureau of Entomology, together with a brief consideration of the characteristics, habits, and life history of the insect, and also the character and extent of its injury to the vine. For this reason the subject matter of this paper deals entirely with experiments conducted during the season of 1911. Readers unfamiliar with the habits of this pest should consult the paper referred to above.



FIG. 1.—The grape leafhopper (*Typhlocyba comes* var. *coloradensis*): Adult. Greatly enlarged. (Author's illustration.)

TREATMENT OF NYMPHS OF THE GRAPE LEAFHOPPER WITH CONTACT SPRAYS.

During the season of 1911 the grape leafhopper was more numerous and destructive to the grapevines in the vineyards of Erie County, Pa., than in 1910. Owing, doubtless, to the higher temperatures prevailing during June and July of this season, the nymphs (see fig. 2) commenced to appear on the leaves at an earlier date, and the development of the nymphal stages of the insect were more rapid than in 1910. Since it is in this the nymphal period before the insect has developed

wings (figs. 2-3) that it is most readily controlled by a contact spray, it was necessary to make the application several days earlier than in the preceding season. In addition to this, the number of days when the maximum number of nymphs was present upon the vines before the earliest to hatch had developed wings was materially lessened,



FIG. 2.—The grape leafhopper: Nymph of the first stage. Greatly enlarged. (Author's illustration.)

thus shortening the period during which the greatest efficiency from the spray applications could be secured. In 1910 the maximum numbers of nymphs of the first brood were present on the underside of the grape leaves about July 15 and spray applications were commenced at that date and were continued until July 26 before many of the nymphs had changed to adults having fully developed wings.

In 1911, however, the maximum numbers of nymphs were present on the leaves by July 5. By July 11 fully 15 per cent of the first nymphs to hatch were changed to the winged form. Thus there was about a week longer time during which the greatest efficiency from the spray application could be secured in the season of 1910 than in 1911. Effective work can be done, however, after many of the nymphs have developed wings, and if the wingless nymphs are still quite numerous upon the leaves the work may be continued with good results. Owing to the more rapid development of the immature stages of the insect in 1911 than in 1910, there was a partial second brood of considerable proportions in 1911, which greatly augmented the injury toward the ripening season. Nevertheless, where vines were thoroughly sprayed against the nymphs of the first brood during the first two weeks in July, only slight injury resulted from the later development of nymphs on these sprayed vines.

FIELD EXPERIMENTS WITH TOBACCO EXTRACTS.

During the summer of 1911 several field experiments, in each case covering several acres, were conducted in vineyards in the township of North East, Pa. In all cases the applications were made against the nymphs about the time the maximum number of the first brood was present on the underside of the grape leaves and before many of the oldest nymphs had changed to the winged form. One thorough application at this time proved sufficient to reduce the

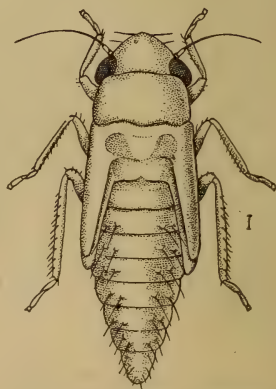


FIG. 3.—The grape leafhopper: Fully developed nymph of the fifth stage. Greatly enlarged. (Author's illustration.)

number of the insects so that those remaining did not materially affect the growth of the vine or the proper ripening of the fruit.

These experiments were conducted in different parts of the township and several types of sprayers were used in making the applications. In all cases the "trailer" method was employed; that is, a trailing hose about 20 feet long was connected to the discharge of the spray pump and a short rod, about $2\frac{1}{2}$ feet long, carrying a large nozzle of the cyclone type set at right angles to the rod was attached to the free end of this lead of hose. This rod is held by the operator, who thrusts the nozzle among the foliage with rapid movements, directing the nozzle upward, so that the liquid is thrown upon the underside of the leaves. (See Pl. I, fig. 1.)

Two forms of commercial tobacco extract were used in these experiments: No. I (blackleaf extract) contained 2.70 per cent nicotine; No. II (blackleaf 40) contained 40 per cent nicotine sulphate. In all of the experiments which follow the tobacco extracts are referred to by number. Tobacco extract No. I refers to the form containing the lower percentage of nicotine, tobacco extract No. II to the form containing the higher percentage of nicotine. At the dilutions used no decided advantage was evidenced in favor of either form of tobacco extract. Both of these substances killed the nymphs that were hit by the spray. The tobacco extract No. I at a dilution of 1 part of extract to 150 parts of water killed all nymphs that were made thoroughly wet by the spray, especially the smaller nymphs, between the first and fourth molts. The full-grown nymphs, unless thoroughly soaked by the spray at this dilution, would sometimes escape, probably because their longer legs held their bodies some distance from the wet surface of the leaf. The tobacco extract No. II was effective at a dilution of 1 part of extract to 1,500 parts of water. In the use of the tobacco extract No. II—as with the tobacco extract No. I, where a large percentage of the nymphs were in the last stage; that is, just about to develop wings (see fig. 3)—a dilution of 1 to 1,200 or 1,300 may be more effective in killing the nymphs. In the several experiments conducted, however, the dilutions varied from 1 to 100 parts of water to 1 to 150 with tobacco extract No. I, and from 1 to 1,000 to 1 to 1,500 with tobacco extract No. II. In all of these variations of dilution apparently equally good results were obtained.

VINEYARD EXPERIMENTS IN 1911.

EXPERIMENT IN VINEYARD OF MR. H. H. HARPER, NORTH EAST, PA.

The east side of the vineyard of Mr. H. H. Harper, North East, Pa., adjoining the highway had been badly infested by the grape leafhopper for several years. Previous to the undertaking of this experiment

the vines had each season made a weaker growth as a result of injury by this pest, and the yield of fruit also was being greatly reduced.

During the season of 1910 several acres on the east side of this vineyard were sprayed with tobacco extract No. I. This treatment resulted in preventing serious injury by the insect. The foliage remained green and healthy throughout the season. There was a greatly increased growth of vine and a higher quality of fruit was secured. The greatest apparent benefit in 1910 was in the great increase in growth of vine.

During the season of 1911 the entire vineyard of 25 acres was sprayed against this pest, which was present in fully as large numbers as in 1910.

A tractor sprayer was used in making the application. (See Pl. I, fig. 1.) A pressure of 100 to 140 pounds was maintained and about 175 gallons of liquid were applied per acre. The application was made by the owner of the vineyard, Mr. H. H. Harper. The spray was applied by the "trailer" method (see Pl. I, fig. 1), using a single large cyclone nozzle. The work was done very carefully and thoroughly. Stops were made at each vine. The pressure was maintained by driving forward the length of the trailer hose. By having a 20-gallon air-chamber on the tractor sprayer a pressure varying from 100 to 140 pounds was secured, rarely dropping below the 100-pound mark. Under favorable working conditions about 3 acres could be covered per day. The tobacco extract No. I was applied at a dilution of 3 quarts to 100 gallons of water. The application was made, on the 3 acres from which our record of yield was secured, on July 6 and 7, when the majority of the nymphs were small but very numerous. The application was very effective, and on account of the thoroughness with which the work was done only a very small percentage of nymphs escaped being killed by the spray.

As a result of this treatment the foliage of the vines remained green throughout the entire season, and the vines made a very heavy growth of new canes. The berries and clusters of fruit were large and of good quality. A record has been kept of the yield for the past three years on 3 acres of this vineyard where the injury by this insect was most apparent at the beginning of the experiment. No attempt to control this pest on these vines was made previous to 1910.

1909.....	Yield of fruit was 262 8-pound baskets of grapes per acre.
1910.....	Yield of fruit was 423 8-pound baskets of grapes per acre.
1911.....	Yield of fruit was 796 8-pound baskets of grapes per acre.

These results show an increase in yield on the first season's treatment of 161 baskets per acre, and for the second season's treatment an increase of 534 baskets per acre over the yield of 1909.

Since the price received per basket of grapes varies each season, it is difficult to compare cash returns one season with another. Prices



FIG. 1.—ROD AND SINGLE CYCLONE NOZZLE USED TO APPLY SPRAY TO UNDERSIDE OF GRAPE FOLIAGE. POWER SUPPLIED BY TRACTOR SPRAYER. VINEYARD OF MR. H. H. HARPER, NORTH EAST, PA. (ORIGINAL.)



FIG. 2.—ROD CARRYING TWO CYCLONE NOZZLES USED TO APPLY SPRAY TO UNDERSIDE OF GRAPE FOLIAGE. POWER SUPPLIED BY COMPRESSED AIR. VINEYARD OF MR. A. I. LOOP, NORTH EAST, PA. (ORIGINAL.)

SPRAYING AGAINST THE GRAPE LEAFHOPPER.

for the past 10 years, however, have averaged about 13 cents per basket. On this basis the cash increase on the treatment in 1910 was \$20.93 per acre, and on the treatment for the second season of 1911 the increase was \$69.42 over that of 1909 before any spray treatment was made against this pest.

The actual cash receipts for the three seasons were as follows:

1909.....	Unsprayed, 11 cents per basket, 262 baskets, \$28.82 per acre.
1910.....	Sprayed, 19 cents per basket, 423 baskets, \$80.37 per acre.
1911.....	Sprayed, 10 cents per basket, 796 baskets, \$79.60 per acre.

Since the actual prices in 1909 and 1911 are almost uniform, the increase in cash return as a result of increased yield is readily seen. This increased cash return in 1911 was \$50.78 per acre.

During these three seasons the general treatment for the vineyard has been the same for each season. The soil was cultivated several times and 420 pounds of fertilizer containing 5 per cent nitrogen, 8 per cent phosphoric acid, and 8 per cent potash were applied each season. A Bordeaux and arsenate of lead spray application, consisting of 4 pounds of copper sulphate, 5 pounds lime, and 3 pounds arsenate of lead to 50 gallons of water, was made just after blossoming. A later application of 1 pound of copper sulphate to 100 gallons of water was made for protection against mildew. Thus the general treatment of the vineyard was good and conducive to the securing of maximum results.

The additional cost of material and labor involved in making the spray application against the grape leafhopper was as follows:

Cost of team per day.....	\$2.25
Boy to drive.....	1.00
Man to handle nozzle.....	1.75
Tobacco extract No. I (strength 3 quarts to 100 gallons of water, applied 175 gallons per acre).....	per gallon.. .85
Cost of material for 3 acres.....	3.36
Total cost of spraying 3 acres per day.....	8.36
Total cost of spraying 1 acre.....	2.79

The power was supplied by a tractor sprayer.

There is no doubt that this tobacco-extract application during the past two seasons has effectively controlled the grape leafhopper and is largely responsible for the increase in crop yield and for the vigorous growth of vine in this vineyard.

EXPERIMENT IN VINEYARD OF MR. W. E. GRAY, NORTH EAST, PA.

The vines in the vineyard of Mr. W. E. Gray, North East, Pa., were badly infested by grape leafhoppers. They were five years old and were bearing a heavy crop of fruit. No spray treatment was given them except with tobacco extract No. I for this pest. About

6 acres were sprayed with tobacco extract No. I. An acre was left unsprayed in the middle of this block.

A gasoline-engine sprayer outfit was used to make the application. The "trailer" method of application was employed.

About 15 per cent of the nymphs of the first brood had developed wings when this spray application was made, July 11 and 12. Nearly all of the nymphs were about full grown and it was thought desirable to use a stronger dilution than in the foregoing experiment. The tobacco extract No. I was used at a dilution of 1 gallon to 100 gallons of water. A pressure of about 125 pounds was maintained throughout. Two leads of hose were used and about 275 gallons of liquid were applied per acre.

Within about three weeks after the application was made the difference in injury on the sprayed and unsprayed grape leaves became noticeable. Upon the unsprayed vines the winged adult "hoppers" were very numerous and the leaves were commencing to turn brown and only a small amount of new growth was being made.

Upon the sprayed vines, on the other hand, the number of winged adults was noticeably much smaller, the foliage was dark green and healthy, and the new growth of vine was quite thrifty throughout the growing season. When the fruit commenced to ripen it became quite evident that the berries and the clusters would be smaller and the fruit not so purple in color upon the unsprayed vines as upon those that were sprayed. Plate II, figure 1, shows a vine in the unsprayed plat. Plate II, figure 2, shows a vine in the sprayed plat. When the crop was harvested the sprayed plat yielded 128 baskets of grapes per acre more than the unsprayed plat. This fruit was sold at 10 cents per basket, giving a gross cash gain of \$12.80 per acre. The cost of spray material and labor of making the application against this pest was as follows:

Team and driver per day.....	\$4.50
Two men to apply spray, \$1.75 per day.....	3.50
Tobacco extract No. I, 275 gallons per acre.....	2.33
Six acres sprayed per day, cost per acre.....	3.66
Increased cash yield per acre, sprayed plat.....	12.80
Cost of material and application per acre.....	3.66
Cash increase per acre on sprayed vines.....	9.14

Thus the net yield on the sprayed plat after deducting all expense of labor and material was \$9.14 per acre. In addition to this increase in crop yield the sprayed vines made a more vigorous and healthy growth than did the unsprayed vines, and the fruit was of much better quality.

EXPERIMENT IN VINEYARD OF MR. J. E. BEATTY, NORTH EAST, PA.

The vineyard of Mr. J. E. Beatty, North East, Pa., had been badly infested by grape leafhoppers for several years. As a result of their injury the cane growth of the vines had been greatly reduced and there had been a corresponding reduction in yield of fruit. Thirteen acres of the worst infested sections of this vineyard were sprayed in 1911. Unfortunately, the spraying was not commenced until about 15 per cent of the first nymphs to hatch had changed to the winged form. The application was made July 12 and 14, using a gasoline-engine power-spraying outfit with two "trailer" leads of hose (see Pl. III, fig. 1). A pressure of 175 pounds was maintained and about 250 gallons of liquid were applied per acre. Tobacco extract No. I was used at a dilution of 1 part to 150 parts of water. This dilution gave good results, even though a large percentage of the nymphs was in the last molt. Within about three weeks after the application was made the foliage of the unsprayed vines commenced to turn brown, and as the season advanced new growth at the end of the canes ceased, whereas on the sprayed vines the foliage remained green and the new growth continued to develop until late in the season. The berries were larger and a darker purple in color upon the sprayed vines. When the crop was harvested the fruit from 300 vines in the unsprayed plat and from the same number of vines on the sprayed plat was weighed and showed a gain of 690 pounds from the sprayed plat, thus giving an increase of 1,380 pounds per acre. This fruit was valued at \$0.015 per pound, showing a gross cash gain of \$20.70 per acre. The cost of spray material and labor of application was as follows:

Team and driver per day.....	\$4. 50
250 gallons of tobacco extract No. I, diluted spray.....	1. 41
Two men handling nozzles.....	3. 50
Six acres sprayed per day, cost per acre.....	2. 74
Increased cash yield per acre.....	20. 70
Cost of material and application.....	2. 74
Net cash gain per acre on sprayed vines.....	17. 96

EXPERIMENT IN VINEYARD OF MR. D. C. BOSTWICK, NORTH EAST, PA.

The grape leafhopper was very numerous in the vineyard of Mr. D. C. Bostwick, North East, Pa., during the summer of 1911. The experiment was undertaken on a block of young vines in the second year of bearing. The vines in this block were quite uniform and carried a heavy crop of fruit. About 15 per cent of the nymphs had transformed to adults when the spray application was made. The spray was applied from July 13 to 15. Three acres were taken in about the middle of the block. One acre on each side of the untreated

acre was sprayed. The work was done with a tractor vineyard sprayer. This machine had been in use several seasons and was not working at its best. The spray was applied by the "trailer" method. Owing to the poor working of the pump a high pressure was not maintained. The pressure varied anywhere from 150 pounds to 50 pounds. Most of the time it ran below 80 pounds. For this reason it was thought necessary by Mr. Bostwick to make the application on both sides of the trellis. In spite of these drawbacks good results were secured. About 275 gallons of liquid were applied per acre. This is more liquid than would have been applied by this machine had it been in good working condition and, in addition, more time was consumed in making the application on both sides of the row. About 600 gallons of spray were applied per day covering about 2½ acres. Tobacco extract No. II was used at a dilution of 1 to 1,300 parts of water.

Labor cost of application per acre.....	\$2. 75
Tobacco extract No. II—1 to 1,300 parts water, per acre.....	2. 58
Total cost of labor and material per acre.....	5. 33

The net yield of grapes from the three plats was as follows:

One acre of vines east of unsprayed plat.....	8,462 pounds grapes
One acre of vines west of unsprayed plat.....	8,327 pounds grapes
One acre of vines, unsprayed plat.....	7,153 pounds grapes

The cash value of the fruit was \$25 per ton, or \$0.0125 per pound.

Cash value of yield on 1 acre east of check.....	\$105. 77
Cash value of yield on 1 acre west of check.....	104. 09
Cash value of yield on 1 acre unsprayed.....	89. 41
Increased yield on west plat per acre over check was 1,309 pounds, or.....	16. 36
Increased yield on west plat per acre over check was 1,174 pounds, or.....	14. 67

Net cash gain on sprayed plats after deducting cost of labor and material:

Gross gain on plat west of check per acre.....	\$16. 36
Total cost of labor and material per acre.....	5. 33
Net gain resulting from spraying per acre.....	11. 03
Gross gain on plat east of check per acre.....	14. 67
Total cost of labor and material per acre.....	5. 33
Net cash gain resulting from spraying per acre.....	9. 34

In addition to this increase in weight of fruit yield it was observed that the berries of the grapes were much larger and of better color than was the fruit on the unsprayed vines. It was also observed that the fruit from the sprayed vines gave a greater weight per basket.

507 baskets from the west plat averaged 20.7 pounds per basket.

497 baskets from the east plat averaged 20.7 pounds per basket.

478 baskets from the unsprayed plat averaged 19 pounds per basket.



FIG. 1.—SHOWING CONDITION OF VINE INJURED BY THE GRAPE LEAFHOPPER IN THE UNSPRAYED PLAT. NOTE LOSS OF FOLIAGE, AND ALSO THE BERRIES FROM THE CLUSTERS. VINEYARD OF MR. W. E. GRAY, NORTH EAST, PA. (ORIGINAL.)



FIG. 2.—SHOWING CONDITION OF VINE IN PLAT SPRAYED WITH TOBACCO EXTRACT NO. 1, AGAINST THE GRAPE LEAFHOPPER. NOTE THE LARGER SIZE OF THE BERRIES IN THE CLUSTERS, HEAVY FOLIAGE AND STRONGER CANE GROWTH. VINEYARD OF MR. W. E. GRAY, NORTH EAST, PA. (ORIGINAL.)

COMPARISON OF SPRAYED AND UNSPRAYED PLATS.



FIG. 1.—GASOLINE-ENGINE SPRAYER SUPPLYING POWER FOR TWO "TRAILER" LEADS OF HOSE, IN SPRAYING AGAINST THE GRAPE LEAFHOPPER. VINEYARD OF MR. J. E. BEATTY, NORTH EAST PA. (ORIGINAL.)



FIG. 2.—GASOLINE-ENGINE SPRAYER SUPPLYING POWER FOR TWO "TRAILER" LEADS OF HOSE IN SPRAYING AGAINST THE GRAPE LEAFHOPPER. VINEYARD OF THE PEACOCK-ROOD COMPANY, WESTFIELD, N. Y. (ORIGINAL.)

SPRAYING AGAINST THE GRAPE LEAFHOPPER.

This shows an average increase in weight of 1.7 pounds per basket for fruit from the sprayed vines. As in the case of all the other experiments, the foliage on the sprayed vines remained green and healthy throughout the season, and new growth of canes continued to be made for a longer period than upon the unsprayed vines.

USE OF COMBINED CONTACT AND POISON SPRAY.

In addition to the experiments described, in which the spray ingredients consisted of either tobacco extract No. I and water or tobacco extract No. II and water, other experiments were made, in one case adding the tobacco extract No. II to Bordeaux mixture and fish-oil soap. In this experiment about two-thirds of an acre of the infested vines was sprayed with the Bordeaux, fish-oil soap, and tobacco extract No. II mixture, and about one-third of an acre was sprayed with tobacco extract No. II and water. So far as could be observed the killing effect of tobacco extract No. II upon the nymphs when mixed with the Bordeaux and soap was in no way lessened; nor was any injurious effect apparent to the leaves and fruit of the vines sprayed with this mixture. The ingredients were used in this mixture at the following dilution: Bordeaux mixture, 3 pounds lime, 3 pounds copper sulphate to 50 gallons of water, plus 2 pounds of fish-oil soap, and tobacco extract No. II at a dilution of 1 to 1,500 parts of the Bordeaux mixture. Tobacco extract No. II at a dilution of 1 to 1,500 parts water.

In another experiment 5 acres of vineyards were sprayed with a mixture of Bordeaux, arsenate of lead, and tobacco extract No. I, at the following dilution, 3 pounds of lime, 3 pounds of copper sulphate, 2 pounds arsenate of lead to 50 gallons of water plus tobacco extract No. I, 1 to 150 parts of the Bordeaux mixture. So far as could be observed the killing effect of the tobacco extract upon the nymphs was not lessened in this mixture nor were any injurious effects from this mixture observed upon the foliage and fruit of the vines. The object of adding the tobacco ingredient to the Bordeaux and the arsenate of lead mixtures is an endeavor to reduce the number of applications made necessary in some instances to control the several insect and fungous enemies attacking the foliage or the fruit of the grapevine. The advisability of applying the tobacco extracts against the grape leafhopper with Bordeaux and arsenate of lead will be a matter for the individual vineyardist to decide after he has made a thorough examination of his vineyard to determine if other insects are present in numbers sufficient to warrant their treatment. The insects which may possibly be infesting the foliage or fruit of the grape at the time of treating the nymphs of the grape leafhopper with the tobacco extracts are the grape rootworm and the grape berry moth.

The second poison application against the grape rootworm to the surface of the leaves of the grape is usually made during the first two

weeks in July. At this time also larvæ of the grapeberry moth are hatching from eggs deposited upon the grape berries. Since it is impossible to cover thoroughly the underside of the grape leaves in spraying for the grape leafhopper without thoroughly wetting the grape clusters it is reasonable to infer that the addition of arsenate of lead would also assist in checking the injury to the grape berries by the larvæ of the grape berry moth. In addition to this the Bordeaux mixture will control the development of mildew on the stems of the grape clusters. The upper surface of the grape leaves also is covered during this process (see Pl. III, fig. 2); hence, if arsenate of lead is present with the tobacco extract this application will control the late emerging beetles of the grape rootworm. As intimated above, the advisability of making this combination of ingredients must be decided by the prevalence and abundance in the vineyard to be treated of the several insects referred to. It should also be borne in mind that this combination treatment is submitted as a suggestion.

The mixing of the tobacco extracts with Bordeaux and arsenate of lead this season was done for the sole purpose of determining if this mixture would be injurious to the grape foliage and berries. As mentioned above, no injurious effect to the vine was observed. Arsenate of lead is the only arsenical that should be used with tobacco extracts, since both arsenite of lime and Paris green cause serious burning of the foliage when mixed with the tobacco extracts.

EFFECT OF GRAPE LEAFHOPPER CONTROL ON QUALITY OF FRUIT

As mentioned in foregoing paragraphs dealing with results secured in these spraying experiments with tobacco extracts, it was observed that in every case where the nymphs were successfully controlled the berries of the grape clusters from these vines were much larger, a darker purple in color, and much sweeter than the fruit from unsprayed vines in the same vineyard. In order to ascertain if there was any marked difference in the sugar content of the grapes from vines growing in the sprayed and unsprayed plats samples representing the average condition of the fruit from sprayed and unsprayed vines from experimental plats in the vineyards of Mr. J. E. Beatty and Mr. W. E. Gray, North East, Pa., were submitted for analysis.

These samples of grapes taken for analysis were forwarded to Prof. Wm. B. Alwood, in charge of Enological Investigations at the laboratory of the Bureau of Chemistry located at Sandusky, Ohio. The samples were there analyzed in connection with the extended studies that Prof. Alwood is making of the chemistry of many varieties of grapes grown in the eastern United States in relation to wine production.

The report received from Prof. Alwood on these samples of grapes from these sprayed and unsprayed experimental plats is given in Table I.

TABLE I.—Analysis of grapes from sprayed and unsprayed grapevines in vineyards of Mr. W. E. Beatty, North East, Pa., in experiments with tobacco extract No. I against nymphs of grape leafhopper. Analysis made at laboratory of United States Bureau of Chemistry under direction of Prof. Wm. B. Alwood.

Serial No.	Variety, grower, locality.	Field number.	Date collected.	Brix at 20° C.	Specific gravity.	Grams per 100 c. c.				Tartaric acid as tartrates.	Condition of fruit and spray treatment, tobacco extract No. I.
						Total solids.	Sugar-free solids.	Total sugar as reducing.	Total acid as tartaric.		
3153	Concord, W. E. Gray, North East, Pa. .....do.....	123	Sept. 20, 1911	17.7	1.0726	18.84	2.66	16.18	0.720	0.549	Medium bunches, good condition, fully ripe. Vines sprayed against grape leafhopper.
3154		124	do.....	11.0	1.0445	11.52	2.91	8.61	.938	.612	
3155	J. E. Beatty, North East, Pa. .....do.....	125	Sept. 21, 1911	18.7	1.0777	20.18	3.00	17.18	.720	.540	Fine bunches, grapes large and in good condition, fully ripe. Vines sprayed against grape leafhopper.
3156		126	do.....	14.5	1.0576	14.93	2.41	12.52	.720	.583	
3261	W. E. Gray, North East, Pa. .....do.....	236	Oct. 11, 1911	18.4	1.0772	20.05	1.71	18.34	.450	.369	Bunches fair, small uneven berries, poor quality, fully ripe. Vines not sprayed against grape leafhopper.
3280		235	do.....	13.1	1.0534	13.83	1.86	11.97	.536	.494	

In comparing the sugar content of the samples from the sprayed and the unsprayed plats it will be observed that the sample from the unsprayed plat under serial No. 3154 showed a sugar content of only 8.61 grams per 100 c. c. as against 16.18 grams per 100 c. c. for sample 3153 from the sprayed plat. In other words, the sample of grapes taken from the plat where the injury to the foliage of the vines by the grape leafhopper was unchecked, by withholding the tobacco-extract spray against the nymphs, contained only about one-half the sugar content that was present in the sample taken from the vines which were sprayed with the tobacco against this insect in the nymphal stage. Samples under serial No. 3156 from the unsprayed plat show a sugar content of 4.66 grams per 100 c. c. less than sample No. 3155, taken from the sprayed plat, and sample No. 3260 from unsprayed plat shows a sugar content of 6.37 grams per 100 c. c. less than sample 3261, taken from sprayed vines in the same vineyard.

In answer to an inquiry as to the approximate difference in value of the fruit from these sprayed and unsprayed plats for use in making wine or grape juice Prof. Alwood gives the following reply:

In response to your question I may say that the sugar content of the three untreated plats is so low that they would have no value whatever for making pure wine or unfermented grape juice and could only be used for some low grade sophisticated products.

Thus the analysis of these samples of fruit indicates that serious injury to the foliage of the grapevine by the grape leafhopper greatly impairs the quality of the fruit. A definite knowledge of this fact furnishes an additional reason why the vineyardist should resort to every practical means at his disposal for the control of this insect whenever it is at all numerous in his vineyard.

CONCLUSION.

The field experiments made during the season of 1911 against the grape leafhopper and recorded in this paper show that a single application of the tobacco extracts applied against this insect in the nymphal stage as a contact spray will reduce its numbers to such an extent that the infested vines will remain in good foliage throughout the season and mature a crop of high-quality fruit.

As indicated by the variation in the time and rapidity in development of the nymphs in 1910 and 1911, it is evident that no definite date for making the spray application can be given. Where the winged adults are at all numerous in the early part of the season the vineyardist is urged to examine the underside of the grape leaves toward the middle and the end of June and to observe the number and size of the nymphs. The spray application to be most effective should be made at about the time the first nymphs to hatch are near the last molt. This is indicated by the length of the wing pads.

(See fig. 3.) At this time the underside of badly infested leaves will be covered by the nymphs in all stages of development. Generally speaking, this condition is likely to occur in the Lake Erie Valley from July 1 to 15. All of the field experiments conducted in 1910 and 1911 were made between these dates and in every instance very satisfactory results were secured. Since the nymphs continue to hatch over a long period, if the spray application is made while the first nymphs to hatch are quite small large numbers are likely to hatch after the spray application has been made, thus necessitating a second application a few weeks later. On the other hand, if the application is withheld until many of the nymphs have developed wings it is doubtful if large vineyard areas can be treated before a large percentage of the nymphs have reached the winged stage. For it must be understood that the tobacco extracts at the dilutions recommended are effective only against the wingless nymphs infesting the underside of the grape foliage. Where it is necessary to treat large areas for this pest, observation would indicate that spray applications should commence during the first week in July.

Observations on the abundance and the extent of injury wrought by this insect pest of the grapevine in the vineyard areas of New York, Pennsylvania, and Ohio bordering on Lake Erie, and also in the vineyard areas of Michigan, indicate that its depredations have increased during the past few years. Progressive vineyardists are commencing to realize that the accumulated injury to the vines by this pest is responsible for curtailment in crop yield and inferiority in quality of fruit wherever it is present on grapevines in large numbers and that steps must be taken to accomplish its control. It is for this reason that the experiments presented in this paper were undertaken, and it is hoped that the results obtained are of sufficient commercial value to encourage grape growers having vineyard areas infested by the grape leafhopper to adopt this method of control.

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DIV. I. INSECTS.

U. S. DEPARTMENT OF AGRICULTURE,
BUREAU OF ENTOMOLOGY—BULLETIN No. 116, Part II.

L. O. HOWARD, Entomologist and Chief of Bureau.

PAPERS ON DECIDUOUS FRUIT INSECTS
AND INSECTICIDES.

APR 30 14

THE GRAPE-BERRY MOTH.

BY

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AND

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ISSUED DECEMBER 18, 1912.



WASHINGTON:
GOVERNMENT PRINTING OFFICE.
1912.

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THE GRAPE-BERRY MOTH.*(Polychrosis viteana Clem.)*

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Entomological Assistants.

INTRODUCTION.

The grape-berry moth, *Polychrosis viteana* Clem. (Pl. IV), is an insect enemy of the grape of long standing in the vineyards of the Lake Erie Valley. Since the first reports of its serious injury to the grape crop near Hudson, Ohio, in 1868, it has been an almost continual menace to grape production in vineyards located along the shores of Lake Erie from Sandusky in Ohio eastward into Pennsylvania and New York. Most of the data dealing with this insect cover a series of life-history records and field experiments conducted during the seasons from 1907 to 1909, inclusive, in connection with the investigations of the grape rootworm and other insect pests of the grapevine which have been carried on at North East, Pa., by the section of the Bureau of Entomology engaged in deciduous fruit insect investigations under the direction of Mr. A. L. Quaintance.

Before entering into a discussion of the detailed life-history studies and remedial measures, a brief résumé of an historical nature is given, showing the attention this insect has received from earlier entomologists. In treating of its origin and distribution it is pointed out that for many years it was confused with the European grape-berry moth, *Eudemis botrana* Schiff., an insect which is very destructive to the berries of grapes in the vineyards of southern Europe and to which it is closely related and bears a very close resemblance, both in appearance and in the manner in which it attacks the grape.

Earlier entomologists credited the grape-berry moth with having a number of food plants, but the studies of the late Prof. M. V. Slingerland in 1903 and 1904 indicate that several other species of *Polychrosis* have been confused with *P. viteana*, and that the latter feeds and reproduces only in the berries of grapes, wild and cultivated. His conclusions are borne out by the observations made during this investigation, for in no case has this insect been reared from anything but blossom clusters and berries of the grape.

Those regions where serious outbreaks of this pest have occurred have been recorded and the habits of the insect and the character of injury are described in detail. Since the character of injury to the grape berry by the grape curculio (*Craponius inæqualis* Say) coincides quite closely with that of the grape-berry moth, the work of this insect is described in order that the injury done by these two insects may not be confused.

A description is given of the stages of the insect, those of the larval and adult forms being quoted from the paper on "Some new species of Polychrosis," by Mr. W. D. Kearfott.¹

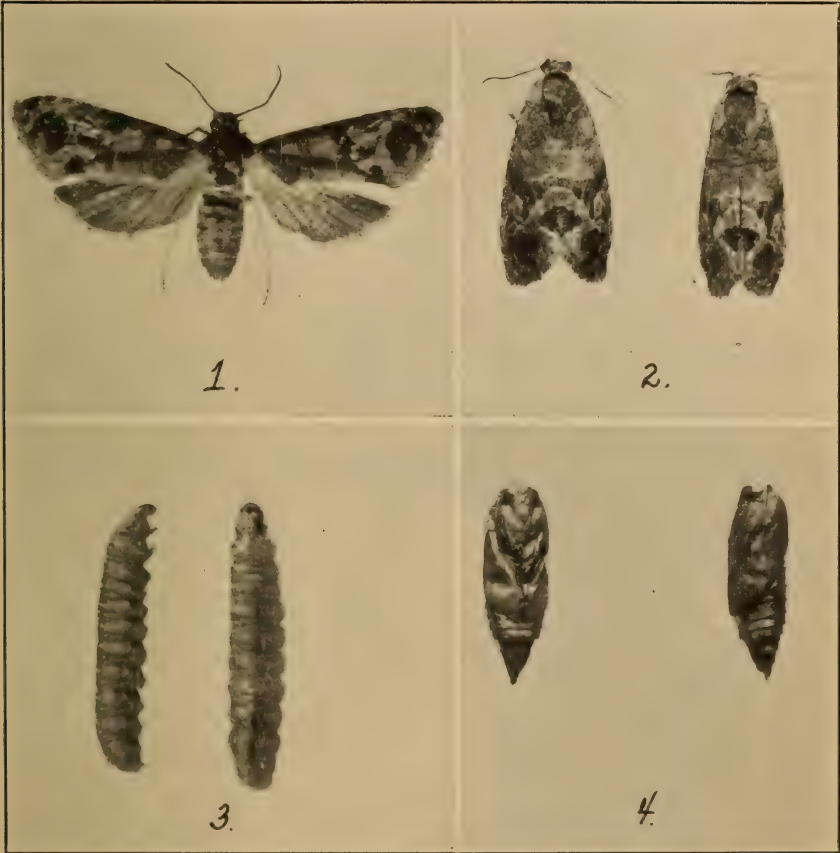
In connection with the rearing experiments it has been found that a large number of hymenopterous parasites prey upon this insect in its larval and pupal stages, and during this investigation 12 additional parasites have been added to the list recorded by Prof. Slingerland in 1904.

During the seasons of 1907 and 1908 the investigation of the grape root-worm occupied the greater part of the time of the force engaged in the study of grape pests. For this reason the life-history studies covering those seasons were rather fragmentary. During the season of 1909, however, the junior author devoted the greater share of his time to a detailed study of the life history of this pest. From the records secured by him in this relation the data covering the various stages of a large number of individuals, presented under the topic of seasonal history for 1909, have been compiled.

These life-history studies indicate that there is only one full brood of larvæ and a partial second brood each season in this region, whereas it was previously supposed that there were two full broods and a partial third brood of larvæ. These records also show the relation of the emergence of the spring brood of moths to the time of blooming of the grape, and the approximate percentage of first-brood larvæ which appear before and after the blooming period, thus indicating the possible relative value of poison-spray applications made against the larvæ before and after the blossoming period.

Field experiments with poison sprays covering several acres of badly infested vineyard were conducted for the three consecutive seasons of 1907, 1908, and 1909, in the vineyard of Mr. W. S. Wheeler, at North East, Pa. These experiments indicate that on account of the extreme variability of infestation of vineyard areas by this pest it is very difficult to lay out an arrangement of plats which will show the relative value of poison-spray applications of varying strength and time of application. Yet there is no doubt that poison-spray applications, made with thoroughness and with due regard to the manner of application, at the time that the larvæ of the first brood

¹ Trans. Amer. Ent. Soc., vol. 30, pp. 292-293, 1904.



THE GRAPE-BERRY MOTH (POLYCHROSIS VITEANA).

FIGS. 1, 2.—ADULT OR MOTH. FIG. 3.—FULL-GROWN LARVÆ. FIG. 4.—PUPÆ. ALL GREATLY ENLARGED. (ORIGINAL.)

are hatching in large numbers, will result in a considerable reduction in the injury wrought to the grape berries by this pest.

Recommendations offered for the control of this insect in regard to the time and manner of making spray applications are based upon the data obtained in the study of the life history and habits of the grape-berry moth during this investigation, correlated with the field experiments and observations covering that period. Since these life-history studies have shown considerable deviations from those previously recorded in regard to the time of appearance of certain stages of the insect and in the number of broods each season, it has been necessary to revise our ideas somewhat as to the relative importance of the spray applications formerly recommended; and since suitable opportunities have not presented themselves for a thorough trial of this revised spray schedule, some of the recommendations along this line are offered rather in the form of suggestions than as definitely demonstrated and proved methods.

HISTORY.

The American species, *Polychrosis viteana*, was first described by Clemens in 1860, in the Proceedings of the Philadelphia Academy of Natural Sciences. In addition to a description of the adult moth Clemens makes some statements as to the habits and food plants of the larva. (See discussion under Food Plants, p. 20.)

In 1869 Packard, in his "Guide to the Study of Insects," has described this insect under the name of *Penthina vitivorana*. In a footnote, however, he states, "It is the *Lobesia botrana* of southern Europe according to Prof. Zeller."

About this date Dr. C. V. Riley sent some specimens of the American-reared species to Mr. P. C. Zeller, of Stettin, Prussia, who identified them as the European species *Lobesia botrana* and Packard's footnote quoted above is doubtless the result of Zeller's identification of the American specimens sent to Europe by Dr. Riley.

From 1870 until 1903 American entomologists accepted the statement of Zeller that the grape-berry moth found in this country was of European origin. In 1903, however, the study of this insect was taken up by Prof. M. V. Slingerland in the vineyards of Chautauqua County, N. Y. Owing chiefly to some variation in the habits of hibernation of the American species from that of the European species—namely, that it makes its overwintering cocoons on fallen leaves, whereas cocoons of the European species are found upon the trellis posts and the trunks of the vines—and since in addition to this the American grape-berry moth is quite common in the fruit of wild grapevines growing at considerable distances from cultivated grapevines, Prof. Slingerland was led to surmise that the American grape-berry moth is a native American species.

In addition to accepting the conclusion of Dr. Riley and Mr. Zeller that the American grape-berry moth is an introduced species, American entomologists previous to Prof. Slingerland's investigations were under the impression that this insect fed and reproduced on several plants other than the grapevine. During his investigation of this insect Prof. Slingerland reared adult moths from many of the plants upon which the grape-berry moth was supposed to feed and in no case was this insect reared from any other plants than from the fruit and blossom clusters of the wild and the cultivated grapevines. Authentic specimens of the European species were secured by him, and these, together with moths reared from other plants and supposed to be the grape-berry moth, were turned over to Mr. W. D. Kearfott for comparison with a large number of American grape-berry moths reared from the fruit of both wild and cultivated grapes.

These comparisons and rearing records made by Mr. Kearfott and Prof. Slingerland have resulted in the former separating the *Polychrosis viteana* of Clemens from the European species and considering it a distinctly native American species feeding and reproducing solely upon the blossom clusters and the fruit of wild and cultivated grapevines. Closely related forms of *Polychrosis* reared from plants other than the grape have been divided by Kearfott into several new species.

ORIGIN AND DISTRIBUTION.

In regard to the origin of the grape-berry moth, as mentioned under the topic dealing with the history of this insect, American entomologists previous to the investigations of Prof. M. V. Slingerland considered it to have been introduced from Europe. On page 56 of Bulletin No. 223 of the Cornell Agricultural Experiment Station issued during 1904, Slingerland gives several paragraphs under the heading "Comparative notes on the American and European grape-berry moths" which present his views and conclusions on this subject. These are as follows:

COMPARATIVE NOTES ON THE AMERICAN AND EUROPEAN GRAPE-BERRY MOTHS.

In 1860, Clemens (Proc. Acad. Nat. Sci. Phila., p. 369) named some moths *Endopiza? viteana* which he reared from caterpillars feeding on grape-berries, wild raspberry fruits, and leaves of sassafras. About eight years later, the grape-feeder attained the rank of a serious pest in vineyards, and two other names were suggested for it. Rathvon (Prac. Farmer, Nov. and Dec., 1868, p. 170 and 48) called it the grape codling-moth (*Carpocapsa vitisella*) and Packard gave it the name of *Penthina vitivorana* (Guide the Study of Insects, p. 336). In 1870, however, Riley sent specimens to Zeller in Prussia, and he said they were identical with the European grape-berry moth (*Eudemis botrana* Schiff.), thus relegating the American names into the synonymy where they have since remained undisturbed. As soon as we found that the insect infesting New York grape-berries was not following the scheduled life-history of the European pest, doubts at once arose regarding the identity of the American

and European grape-berry moths in spite of Zeller's dictum which had stood unquestioned for over thirty years. Several authentic specimens of the European moths were obtained and have been critically compared by an expert, Mr. W. D. Kearfott, with dozens of the moths reared from American grapes, both wild and cultivated, and also with the type specimens of Clemens's *viteana* and some of Riley's material. Briefly stated, the conclusion is that the American grape-berry moth is Clemens's *viteana* which is distinct and easily separable from the European insect. This conclusion, based on a comparison of the moths alone, is strongly supported by our observations on the difference in the life-history of the two insects, and the fact that the American insect freely infests both our wild and cultivated grapes.

The general coloration of the moth of the European insect * * * is an ashy gray with pale grayish hind wings, while the American moths range a trifle smaller, and are of a general purplish-brown color with smoky-brown hind wings. And the large outer marginal patch near the fringe of the front wings affords a sure and easy distinguishing mark between the two insects. In the European *botrana*, the outer edge of this pale olive-green patch is rounded and not indented below, while in the American *viteana* this dark-brown patch is indented above the anal angle by a spur of the lighter ground color of the wing. This characteristic difference is well shown in Fig. 24. There is considerable variation in the indentation of this patch in *viteana* but it is always present; we have a few specimens where the indentation extends through the patch, thus making it smaller and separating off a narrow strip of it on the edge of the wing, but this usually occurs on one wing only, the other being nearly normally indented. Superficially the two insects are marked much alike, but are easily distinguished by the characteristic differences in general coloration and the outer marginal patch. Both species are somewhat variable in size and markings, as shown in Figs. 20 and 24.

An excellent, detailed, 75-page account by G. Del Guercio of the European grape-berry moth was published in 1889 (Nouve Relazioni R. Stazione di Entomologia Agraria di Firenze, Serie Prima, No. I, p. 117-193). In a careful comparison of specimens of the early stages of our American species with Guercio's descriptions, we found but few minor differences.

The bulletin from which this quotation was made also contains descriptions, on pages 57 to 59, of several new species of Polychrosis, by Mr. W. D. Kearfott, under the title "Descriptive notes of some new species of American moths that have been confused with the grape-berry moth." The verdict of Prof. Slingerland that *viteana* is a native American species is now quite generally accepted and has been followed in the preparation of this paper.

According to existing authentic records of its occurrence in North America its distribution is confined to those eastern and west-central States of the United States and to those eastern provinces of Canada in which the growth of wild and improved varieties of American species of grapes is of considerable extent (see fig. 4). For, so far as is known at the present time, this insect confines its depredations entirely to the fruit of native and improved varieties of American species of grapes. It is not known to occur in the vineyards of the Pacific slope and of adjoining States where the grapevines grown are almost entirely of the European or vinifera type.

The States from which the grape-berry moth has been recorded are given in about the order of destructive occurrence of the insect

as follows: Ohio, New York, Pennsylvania, Indiana, Illinois, Michigan, Missouri, New Jersey, Virginia, Maryland, West Virginia, Iowa, Delaware, and Arkansas. It is also reported as occurring in a number of other States in which the production of grapes is very limited, namely, Massachusetts, Connecticut, Kentucky, Kansas, Texas, Nebraska, and Wisconsin. In Canada it is reported from the vicinity of London, Ontario.¹

FOOD PLANTS.

When Clemens described the American grape-berry moth in 1860 he recorded it as having several food plants and made the following statements concerning the habits of the larva:

The larva feeds on the fruit of the grape in September; a silken gallery is attached to the external opening of the fruit. Its head is dark brownish; shield blackish; body

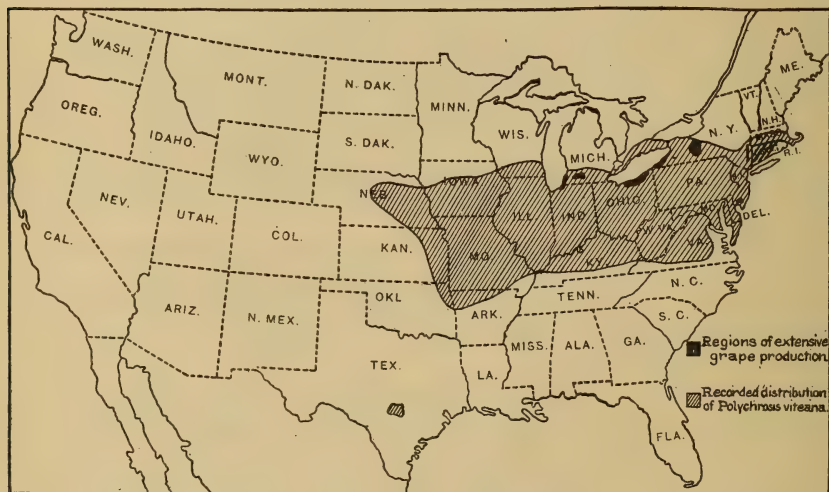


FIG. 4.—Map showing distribution of the grape-berry moth (*Polychrosis viteana*). (Original.)

immaculate dark green. It may likewise be taken on the fruit of wild raspberry. The individual feeding on the grape undergoes transformation by weaving a cocoon on the surface of the ground and that from the raspberry under an excised and turned down portion of leaf. This, however, may not be its normal habit.

Clemens also records it as feeding on leaves of sassafras.

Since that time a number of other entomologists have added several food plants to this list. Packard, in 1868, stated that the first brood feeds on the leaves and tendrils of the grape.

Slingerland gives the following list of food plants added by entomologists during the next thirty years:

Blackberry blossoms (Riley, 1870), roses and *Vernonia* or ironweed (Murtfeldt, 1880 and 1882), tulip-tree leaves and swollen stems of *Amorpha* (Fernald, 1882), flower-buds

¹ SAUNDERS, WM.—Can. Ent., vol. 14, pp. 178-180, 1882.

of common thistle (Coquillett, 1883), berries of wild grapes (Bruner, 1895), grape tendrils and blossoms, seed bunches of sumac, leaves of magnolia, phylloxera lice and their galls (Marlatt, 1896), and moths bred from flower heads of thoroughwort or boneset and *Ambrosia trifida* have been classed with the grape-berry moth in collections.

In all of the rearings of allied moths made by Kearfott and Slingerland, *viteana* was not obtained from any plants other than the grape. This is also true of the rearings made at North East, Pa., during the investigations of grape insect pests which have been conducted there from 1907 to 1911 by the Bureau of Entomology. It is therefore reasonably safe to state that this insect confined its feeding and reproduction to the blossom clusters and berries of the wild and the cultivated grape.

Mr. Kearfott prefaces his paper¹ with the following statement:

The following notes are from breeding records extending over the past four years, which have convinced me that each of the species described, as well as a number of others waiting for better material, completes its entire yearly cycle of two or three broods on a single food-plant and also with little doubt each food-plant supports a separate and distinct species. This does not seem unreasonable, for in Europe there are twenty described species of the genus *Polychrosis*.

OCCURRENCE OF THE GRAPE-BERRY MOTH IN DESTRUCTIVE NUMBERS.

The earliest record of serious injury by the grape-berry moth in America is from Mr. M. C. Read, of Hudson, Ohio, in 1869. He states that during that season and for several seasons preceding this date this insect had been very injurious to grapes in vineyards in the vicinity of Hudson, Ohio.²

Walsh in 1869 states that several persons reported to him observations of its occurrence in injurious numbers in different parts of Missouri and southern Illinois. Riley makes the statement that in 1868 it was common in vineyards in Missouri along the Pacific & Iron Mountain Railroad, and that it was equally common around Alton, Ill. He was also informed that it had ruined 50 per cent of the grapes around Cleveland, Ohio, during the same season.

In 1870 Townend Glover reported it as occurring in large numbers on the fruit of grapevines in Maryland. In 1882 Saunders reported a serious outbreak of the pest in Canada, in vineyards in the vicinity of London, Ontario. In 1885 Dr. F. M. Goding reported it as being very injurious in vineyards near Ancona, Ill. Prof. F. M. Webster reported it as destroying 50 per cent of the grape crop in the vicinity of Cleveland, Ohio, in 1893. In this same year Prof. H. Osborn reported it as being injurious in vineyards near Des Moines, Iowa. In 1898 Prof. Webster again reported it as being very destructive in the vicinity of Cleveland and Gypsum, Ohio. In 1903 and again in 1905 Mr. A. F. Burgess found it very injurious in vineyards in the

¹ Bul. 223, Cornell Univ. Agr. Exp. Sta., pp. 57-59.

² Riley, Missouri Report, 1869.

vicinity of Euclid, Ohio. He also reported it as being very injurious in vineyards on Kelleys Island, Ohio, in 1905. In 1906 it was reported by H. A. Gossard and J. S. Houser as again being very injurious in Ohio on Kelleys Island, South and Middle Bass Islands, and also in vineyards along Lake Erie east and west of Cleveland.

Prof. Slingerland (*loc. cit.*) reported that a correspondent informed him that the crop was entirely ruined by this insect in some vineyards at North East, Pa., in 1896. The same author makes the following statement in regard to serious infestations in the State of New York:

There are doubtless more or less "wormy" grapes each year in practically every vineyard in New York State, so that the grape-berry moth is a constant menace. But it seems seldom to have been injurious since 1873, when it was first reported as increasing in numbers in the Hudson Valley. In 1898 it was a serious pest in the vineyard of a correspondent at Kendall, N. Y., and in 1902 reports reached us of its ravages all through the Chautauqua grapebelt. From portions of some vineyards near Brocton [N. Y.], a loss of from 25 to 50 per cent was reported, and in one case 90 per cent of the fruit was ruined.

During the investigations of grape insects at North East, Pa., by the Bureau of Entomology, the grape-berry moth was found to be very injurious over limited vineyard areas in this township in 1906, 1907, and 1908. In 1909 and 1910 the injury was not so great. In 1911, however, the infestation was noted to be quite heavy in two or three vineyards. Serious injury was also noted in vineyards in Ohio along the lake shore east and west of Cleveland, and also near Sandusky.

It is evident from these records that this is a serious enemy of the grape, of long standing and wide distribution throughout the vineyard areas of the eastern United States.

In the aggregate the crop loss due to its depredations must be very great, but owing to the irregularity with which the infestation occurs over vineyard areas it is exceedingly difficult to estimate the amount. For this reason the insect has not been subject to the persistent and painstaking efforts for its control on the part of the vineyardist that so destructive an insect pest seems to warrant.

HABITS OF THE ADULT OR MOTH.

The adult grape-berry moth is rarely seen in the vineyard, even in locations where it is quite abundant. It is a small slaty-brown moth with peculiar shaded brown markings on the forewings which render it quite inconspicuous upon the canes of the grapevine. When at rest with the wings folded it is about one-fourth of an inch long (see Pl. IV, fig. 2) and measures less than one-half inch across the outspread wings (see Pl. IV, fig. 1). In captivity in the rearing cages the moths were inactive during the day, remaining stationary upon the canes of the vine beneath the denser foliage or upon the woodwork of the

cage. Their position could be located only after an extended and careful search, so closely did their coloration harmonize with the background upon which they were at rest. Toward evening they became active, flying about the rearing cage and among the foliage of the vine, and at this time of day oviposition on the blossom clusters and berries doubtless occurs. At no time, however, were the females observed in the act of ovipositing. Practically all of the egg deposition on grape berries in the rearing cages occurred at night; hence there is no doubt that the moth is largely nocturnal in its activities. It has been observed quite frequently, however, that in the vineyards egg deposition is much heavier upon the grape clusters that are enveloped in dense foliage. This would indicate that conditions of subdued light are more favorable to oviposition than are exposed positions.

HABITS AND CHARACTER OF INJURY OF THE LARVA.

It is in the larval or caterpillar stage that this insect is injurious to the grape, and, as the popular name of the insect indicates, the berry or fruit is the part of the plant which it attacks. In 1868 Packard recorded the larva as feeding on the leaves, but the next year he corrected this error, and later observations by entomologists have failed to confirm this habit. The first larvæ to hatch are from eggs which are laid by the earliest emerging moths in spring and are doubtless deposited on the unexpanded blossom buds or on the stems of the blossom clusters. These larvæ attack the blossoms and the tiny berries. In the course of its movements, which must cover the entire blossom cluster, the larva spins a silken web. This web binds to each other and to the stem the dried corollas, stamens, and partly devoured berries, forming a conspicuous mass (see fig. 5). Usually, however, these webs formed during the blossoming period of the grape are not very numerous except in those portions of vineyards where the infestation is very heavy. In addition to attacking the blossoms and small berries of the young grape clusters the larva sometimes burrows into the stem, destroying a part of the cluster (see Pl. V, fig. 1). As the berries increase in size the small, scale-like, semitransparent eggs are readily found upon them. The portion of the berry at which the larva enters takes on a conspicuous purple color, and not infrequently the infested berries crack open as illustrated in Plate V, figure 2. In addition to destroying the berry first attacked, the larva connects it to an adjacent berry by silken strands, forming a tunnel between the partly injured berry and the sound one. This forms an avenue of escape for the larva when the berry first attacked is so badly injured that it breaks away from the stem (see Pl. V, fig. 2). When the larvæ of the first brood have

attained full growth they leave the web or the partly grown fruit and travel to the leaves, upon which they form pupal cases. The



FIG. 5.—Injury to grape cluster by larva of grape-berry moth during and just after the blooming period. (Original.)

larva makes the pupal case by cutting away a portion of the leaf and drawing the free edge down to the surface of the leaf with strands



FIG. 6.—Pupal cases made on grape leaf by full-grown larvæ of the first brood of the grape-berry moth. (Original.)

of silk (see fig. 6). The inside of the case is lined with the same silken material. In this case the larva transforms to the pupa (see



FIG. 1.—SHOWING DESTRUCTION OF PORTION OF GRAPE CLUSTER, AS A RESULT OF BORING OF LARVA INTO STEM; NOTE ALSO DRAWING TOGETHER OF BERRIES BY THE WEBB. (ORIGINAL.)



FIG. 2.—SHOWING CRACKING OF INFESTED BERRIES AND ALSO THE WAY IN WHICH BERRIES FIRST ATTACKED ARE SECURED BY WEB TO BERRIES WHICH ARE ATTACKED LATER IN THE DEVELOPMENT OF THE LARVA. (ORIGINAL.)

INJURY TO GRAPES BY LARVÆ OF FIRST BROOD OF GRAPE-BERRY MOTH.



FIG. 2.—INJURY TO BERRIES BY LARVÆ JUST PREVIOUS TO HARVESTING OF FRUIT. (ORIGINAL.)



FIG. 1.—SHOWING CLUSTERS OF CONCORD GRAPES FROM WHICH INFESTED BERRIES HAVE BEEN REMOVED. (ORIGINAL.)

INJURY TO GRAPES BY LARVÆ OF SECOND BROOD OF GRAPE-BERRY MOTH.

Pl. IV, fig. 4), and the latter emerges as an adult moth (Pl. IV, fig. 1). These moths of the first brood deposit their eggs on the now nearly full-grown berries (see fig. 7). These second-brood eggs are usually more numerous than those of the first brood, if the infestation is at all serious. They are deposited upon the surface of the fruit and are quite conspicuous as white scale-like spots (see fig. 7). When the infestation is very heavy nearly all of the berries

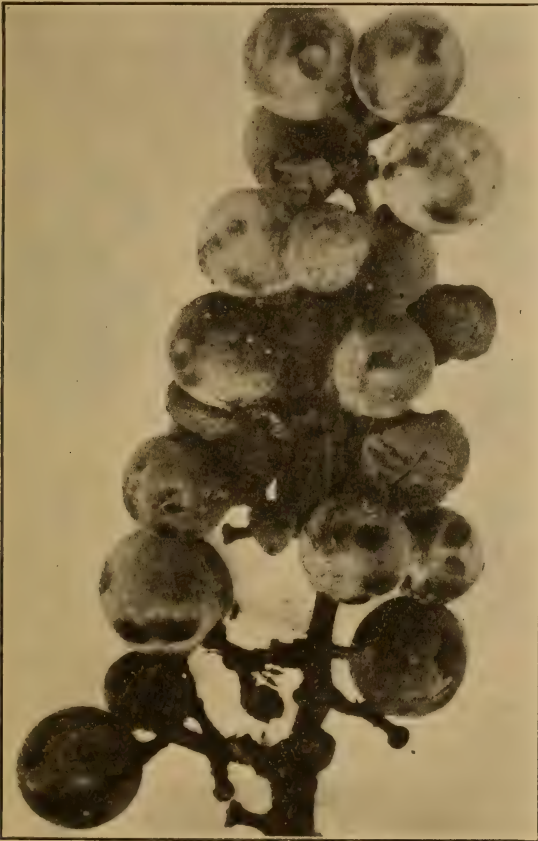


FIG. 7.—Cluster of Concord grapes on which many second-brood eggs of the grape-berry moth are present. The white spots indicate the appearance and position of the eggs. Eggs with black centers were parasitized. (Original.)

in the cluster may be attacked and the fruit rendered worthless. The larva feeds upon the pulp of the fruit and sometimes attacks the seeds before these commence to harden. By the time the grape crop is ready to harvest it is not unusual to find large numbers of clusters injured to the extent shown in Plate VI, figure 1. In Plate VI, figure 2, full-grown larvæ of the second brood are shown in the act of leaving the fruit for hibernation.

DESTRUCTIVENESS OF THE LARVA.

As indicated under the caption dealing with the character of injury, a single larva of the first brood may destroy almost an entire cluster about the time the grapes are in bloom (see fig. 5). For some time after blooming a larva is capable of destroying several berries or even a large portion of the cluster by attacking the stem. When berries are attacked after they have attained the size of a pea, however, rarely more than two or three are destroyed by a single larva. Yet this restriction in the number of berries injured by the individual larva is doubtless more than offset by the great increase in the number of larvæ of the second brood, which are not infrequently

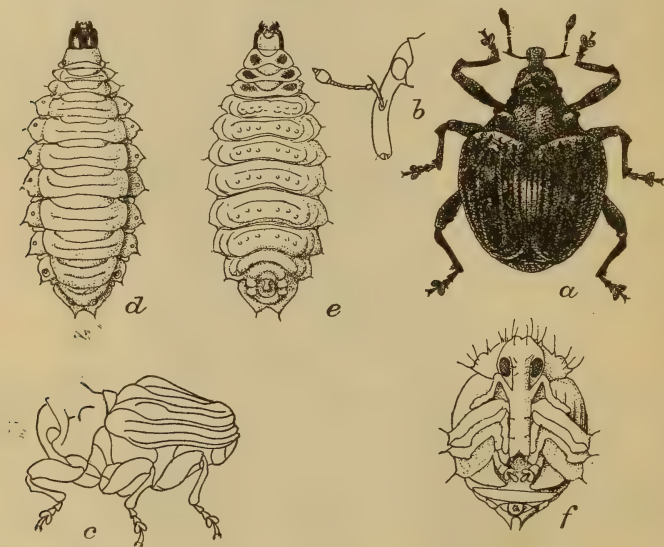


FIG. 8.—The grape curculio (*Craponius inæqualis*): *a*, Adult, or beetle, from above; *b*, head, antenna, and beak of same, from side; *c*, adult, from side; *d*, larva, from above; *e*, same, from below; *f*, pupa, from below. All much enlarged. (From Farmers' Bulletin 284.)

present in sufficient numbers to destroy nearly all of the berries in the cluster, as is shown in Plate VI, figure 1. From these clusters all the infested berries had been removed previous to taking the photograph.

OTHER INSECTS WHOSE INJURY TO GRAPE BERRIES RESEMBLES THAT CAUSED BY THE LARVA OF THE GRAPE-BERRY MOTH.

The only other insect attacking the berries of the grape whose injury to the fruit closely resembles that of the grape-berry moth is the grape curculio, *Craponius inæqualis* Say. This insect, however (see fig. 8, *a*), is one of the snout-beetles or curculios. Its injury to the grape berry is similar to that of the plum curculio upon the plum and other tree fruits. The grape curculio punctures the skin of the

green grape and eats out a small cavity beneath the skin in which to deposit its egg. This injury causes a purple spot on the surface of the berry similar to that which occurs at the point of entrance on the berry by the larva of the grape-berry moth. Where the two insects occur in the same vineyard their work is likely to be confused. The larva hatching from the egg of the grape curculio is a small, white, legless grub which tunnels to the center of the berry, feeds on the pulp, and frequently attacks the seed in much the same manner as does the larva of the grape-berry moth (see fig. 9, *d*). The larva of the grape-berry moth, however, is a caterpillar of a green or purplish color (see Pl. IV, fig. 3), having six well-developed legs and a longer and more slender body, is very active in its movements, and when disturbed by cutting open the berry which it infests is likely to wriggle from its tunnel and drop to the ground.

The grape curculio is not a common pest in the vineyards of New York State and in the vicinity of the Great Lakes.

During the investigation of grape insects covering the past five years only two light infestations of this insect have been observed in the vineyards of the Lake Erie Valley. It is, however, a common vineyard pest in West Virginia and in many of the States of the Mississippi Valley and the Middle West.

Since the beetles feed on the foliage of the grapevine it is readily controlled by spraying with arsenate of lead, the applications being made at the same date as recommended against the larvæ of the grape-berry moth and the grape rootworm.

An account of the life history and habits of the grape curculio, including methods for its control, are given in Farmers' Bulletin 284 on "Insect and Fungous Enemies of the Grape East of the Rocky Mountains," by Messrs. A. L. Quaintance and C. L. Shear.

There is also a minute chalcis fly,¹ *Evoxyzoma vitis* Saunders, which caused some alarm among vineyardists in Canada when it was discovered in the vicinity of London, Ontario, by Saunders in

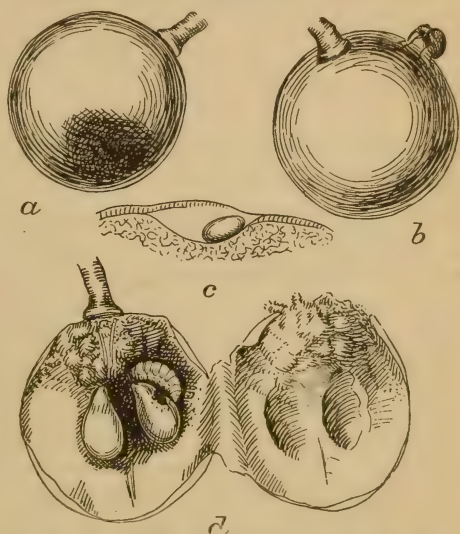


FIG. 9.—Work of the grape curculio in berry of grape: *a*, Berry from which grub or larva has emerged; *b*, adult or weevil ovipositing on berry; *c*, enlarged section of portion of berry, showing egg cavity and egg; *d*, injured berry cut open, showing larva at work. *a*, *b*, *d*, Enlarged; *c*, highly magnified. (From Farmers' Bulletin 284.)

¹ Can. Farmer, October 15, 1868, p. 316.

1868, infesting seeds of several varieties of cultivated grapes, namely, Clinton, Delaware, Rogers No. 4, and an unnamed seedling variety. Since that time, however, this insect has failed to materialize as a serious enemy to cultivated varieties of grapes. The adult is a minute hymenopterous fly. The female insect deposits its eggs by means of its long ovipositor through the pulp of the grape berry into the seed. The larva hatching from this egg is a minute grub, which feeds upon the pulp within the seed, in which it reaches full development. Grape berries infested by this pest shrivel and drop before the ripening period. This shriveled condition of the berries infested by this grape-seed chalcis is the only evidence of its injury that is likely to be confused with that of the larva of the grape-berry moth.

DESCRIPTION.

THE EGG.

The eggs of the grape-berry moth are oval, scale-like, semitransparent bodies about 1.75 mm. by 1.25 mm. in diameter. They are solidly glued to the surface of the berry and although quite flat they are somewhat more rounded and smaller than those of the codling moth, which they greatly resemble. Before the larvæ hatch from them the eggs are not very conspicuous, especially upon the green berries, since on account of their transparency they become lost in the ground color of the berry. The eggshell is finely reticulate. The development of the larva can be readily observed through the transparent shell. After the larva hatches the eggshell remains upon the surface of the berry and can be more readily seen than the egg itself and appears as a whitish spot possessing a pearly iridescence. Upon the purple background of the ripening fruit the eggs are much more conspicuous than upon the green berries, as shown in figure 7. The eggs with dark centers have been parasitized by the egg parasite *Trichogramma pretiosum* Riley.

THE LARVA.¹

Larva:—9 to 10 mm. Cylindrical, rather robust, tapering from [segment] 4 to head and [segment] 8 to anal segment. Pale olivaceous-green, with a reddish or purplish tinge from food. Head flattened, slightly bilobed, luteous green on upper parts of lobes, discolored by brown in front; mouth parts and a horizontal dash on side of each lobe below middle black. Pro-thoracic shield large but narrow, luteous brown, bisected by pale green dorsal line. Thoracic feet black, green between joints. Tubercles plates moderate, a slight shade darker than skin, shining. Anal plate not chitinous.

¹ Description by W. D. Kearfott, Trans. Amer. Ent. Soc., vol. 30, p. 293, 1904.

THE PUPA.

The pupæ are 5 mm. (three-sixteenths inch) in length, light greenish brown, with eyes and caudal border of abdominal segments and last two or three segments darker brown. There is a row of coarse short spines near the cephalic border, a row of finer ones along the caudal border of the dorsum of each abdominal segment, and eight bristles, with recurved tips for hooking into the silken cocoon, occur around the tip of the abdomen. On emergence of the adult from the cocoon the exuviae are drawn about halfway out of the cocoon.

THE ADULT.¹

Endopiza viteana Clem., Proc. Acad. Nat. Sci. Phila. 359, 1860.

Carpocapsa vitisella, Rathvon, Prac. Farmer, p. 170, 1868.

Penthina vitivorana Pack., Guide Study Ins., 336, 1869.

Head, thorax, palpi light brown, specked with darker brown, lower and outer sides and tips of palpi and posterior thoracic tuft dark brown.

Forewing:—Ground color, lilaceous-blue, middle fascia and large spots brown, overlaid with much black. Costal spots lighter brown. A dash of white about middle of outer third.

Base to middle fascia lilaceous-blue, inner fascia almost obsolete, represented by a narrow band of black scales, each fringed with light brown, from dorsum but not reaching costa by a quarter, three small spots and two small ones between them of brown-black scales on costa before middle fascia. And in the same space on dorsum four black dots, the dorsal margin narrowly overlaid with light fuscous, brown and black scales, causing a mottled appearance.

The middle fascia is evenly convex on its inner edge, and is of almost even width throughout, except at about middle of wing, the outer edge curves downward and outward at right angles to the band, and then turns abruptly upward to costa (in the curve thus formed rests the white oblique patch) from outer end of this branch the outer line of fascia continues inwardly oblique to costa, slightly indented, the lower half of fascia triangular. Color smoky-black on upper half, a small patch of same at one-third above dorsum, otherwise smoky brown, lightest at dorsum. Before anal angle is a triangular brown spot. Above the angle an irregular rounded blotch of brown and black, indented at its lower outward corner by a spur of the ground color, its outline also broken by a spur of ground color on its outer upper edge. Apical spot flatly triangular. Ground color of costal margin between fascia and apex, whitish blue, four brown costal spots in this space, the inner a mere outwardly oblique line curving into outer lower end of second spot, latter and fourth are triangular-oblique, third spot rectangular. Below these spots and above the white patch are scattered a few brown scales. Cilia bluish grey, darker at apex and light fuscous at anal angle. Underside dark fuscous, whitish below fold, three geminated whitish spots on costa before apex, and a number of others on extreme edge of costa only, between these and base, cilia darker with narrow light subciliate line.

Abdomen smoky black, with metallic reflection, anal tuft silvery-white above, yellowish beneath, tipped with dark fuscous; underside abdomen whitish; legs same inwardly and between joints, outwardly smoky-black.

Hind wing:—Smoky fuscous, lighter towards base, darkest at apex, cilia paler; underside fuscous.

¹ Description by W. D. Kearfott, Trans. Amer. Ent. Soc., vol. 30, pp. 292-293, 1904.

SEASONAL HISTORY.

Observations on the life history of the grape-berry moth extend over the seasons of 1907, 1908, and 1909. During the latter year special efforts were made to obtain complete records on the development of the insect in its various stages. In many respects the seasonal conditions during 1907 and 1908 were unusual, the spring of 1907 being late and the entire season of 1908 unusually early. The season of 1909 was in most respects normal.

LIFE-HISTORY STUDIES IN 1909.

The emergence record of the spring brood of the grape-berry moth was secured from leaves upon which larvæ had made cocoons during the fall of 1908. These leaves were left out of doors in a cage all

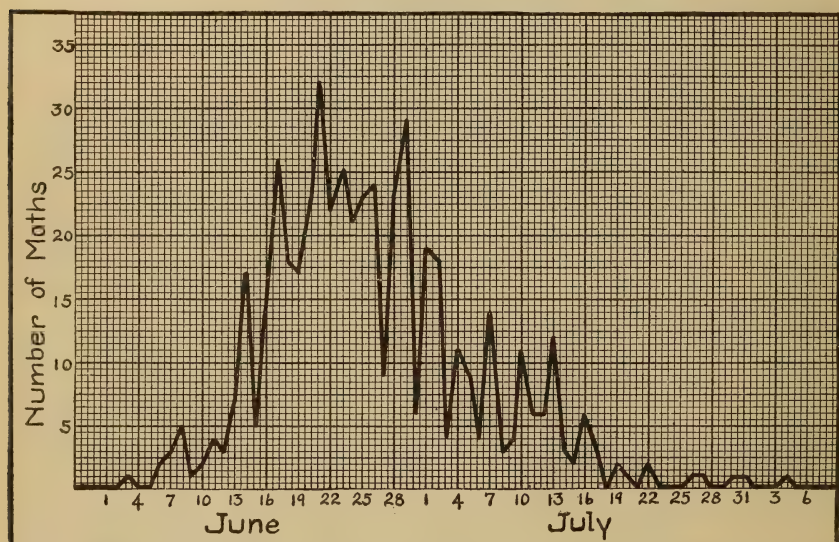


FIG. 10.—Diagram showing time of emergence of spring-brood moths of the grape-berry moth in 1909, at North East, Pa. (Original.)

winter so as to be subject, as nearly as possible, to natural conditions. On May 17, 1909, 1,000 of these cocoons were separated from this mass of leaves and placed in jars in an outdoor rearing shelter (see Pl. VII, fig. 1) and the following emergence record was secured by a daily examination of the jars and the removal of all moths.

SPRING BROOD OF MOTHS.

Time of emergence of spring brood of moths.—Table I gives the emergence of all the moths from these jars. The total number of moths to emerge was 507. The number of moths that emerged from June 3 to June 14 was 28, or 5.5 per cent; from June 14 to July 14, 455, or 89.8 per cent; from July 14 to August 5, 24, or 4.7 per cent. The maximum emergence occurred June 21. (See fig. 10, showing time of emergence of the spring-brood moths.)

TABLE I.—*Time of emergence of moths of the grape-berry moth in the spring of 1909 at North East, Pa.*

Date of emergence.	Number of moths.	Date of emergence.	Number of moths.	Date of emergence.	Number of moths.	Date of emergence.	Number of moths.	Date of emergence.	Number of moths.
June 3	1	June 18	18	July 1	19	July 14	3	July 30	1
6	2	19	17	2	18	15	2	31	1
7	3	20	23	3	4	16	6	Aug. 1	0
8	5	21	32	4	11	17	3	2	0
9	1	22	22	5	9	19	2	3	0
10	2	23	25	6	4	20	1	4	1
11	4	24	21	7	14	22	2	5	0
12	3	25	23	8	3	23	0	Total.	507
13	7	26	24	9	4	24	0		
14	17	27	9	10	11	25	0		
15	5	28	23	11	6	26	1		
16	14	29	29	12	6	27	1		
17	26	30	6	13	12	28	0		

Since the blossoming period of the grape in the Lake Erie Valley occurs usually from June 13 to June 20, this emergence record of the spring moths indicates that the maximum emergence takes place during and after the blossoming period. This record also indicates that the small percentage of webs containing larvæ found in the blossom clusters does not represent the full spring brood from spring-emerging moths, as has been supposed by some investigators, but merely represents the offspring of a very small percentage of the earliest appearing moths.

Oviposition of spring-emerging moths in confinement.—The female grape-berry moth does not oviposit readily in confinement, which accounts for the somewhat meager oviposition records obtained. No eggs were observed in our rearing cages until the berries of the grape were formed and those found were always deposited upon the berries.

TABLE II.—*Oviposition of spring moths of the grape-berry moth in stock jars at North, East, Pa., 1909.*

No. of stock jar.	Number of moths.	Date of—			Days—		
		Emergence of moths.	First oviposition.	Last oviposition.	Before oviposition.	Of oviposition.	From emergence to last oviposition.
1	10	June 17	July 1	July 5	14	5	18
2	30	June 18	June 24	July 2	6	9	14
3	15	June 19	...do...	June 30	5	7	11
4	20	June 20	June 30	...do...	10	1	10
5	46	(June 21	} June 25	July 5	4	11	14
6	12	June 22		July 7	4	11	14
7	16	June 23	June 27	July 1	7	1	7
8	20	June 24	July 1	July 1	4	10	13
9	23	June 25	June 29	July 8	4	13	16
10	29	June 26	June 30	July 12	4	3	10
		June 29	July 7	July 9	8		
Average.....					6.6	7.1	12.7
Maximum.....					14	13	18
Minimum.....					4	1	7

Table II gives a record of oviposition by spring-emerging moths secured during the season of 1909. This table gives the number of days between emergence of the moth and the first oviposition and also the number of days between emergence and the last oviposition. The minimum period before first oviposition was 4 days; the average 6.6 days; the maximum 13 days. The average period between the first and last ovipositions was 7.1 days. The longest period between emergence and the last oviposition was 18 days.

Length of life of spring brood of moths.—Records from our rearing cages show that many of the moths will live in confinement for a number of days, especially when food in the form of honey or sweetened water is supplied. Table III gives the length of life of 76 moths, showing that the minimum life period was 4 days, the average 12.9 days, and the maximum 23 days. The average length of life of the moths recorded in this experiment very closely approximates that of the moths recorded in Table II, which was 12.7 days.

TABLE III.—*Length of life of moths of the spring brood of the grape-berry moth in confinement, with food, at North East, Pa., in 1909.*

Number of moths.	Date—		Length of life.	Number of moths.	Date—		Length of life.
	Emerged.	Dead.			Emerged.	Dead.	
			<i>Days.</i>				<i>Days.</i>
4.....	June 19	July 3	14	3.....	June 23	July 16	23
4.....	do....	July 6	17	10.....	June 24	July 2	8
4.....	do....	July 7	18	1.....	do....	July 7	13
2.....	do....	July 8	19	1.....	do....	July 9	15
1.....	do....	July 9	20	1.....	do....	July 11	17
6.....	June 20	June 29	9	4.....	July 4	July 12	8
5.....	do....	July 1	11	2.....	do....	July 14	10
8.....	do....	July 3	13	1.....	do....	July 15	11
2.....	do....	July 9	19	1.....	do....	July 16	12
6.....	June 23	July 8	15	3.....	July 13	July 17	4
1.....	do....	July 10	17	2.....	do....	July 24	11
2.....	do....	July 12	19	2.....	do....	July 26	13

Total number of moths..... 76

Length of life:

Average..... days: 12.9

Maximum..... do.... 23

Minimum..... do.... 4

FIRST GENERATION.

Incubation period of first-brood eggs.—Table IV gives a record of the length of the egg stage for 21 eggs of the first brood deposited on grape berries in the field rearing cage. The minimum length of the egg stage for this number of eggs was 4 days, the average 6 days, and the maximum 8 days.



FIG. 1.—PORTION OF OUTDOOR SHELTER USED IN THE REARING OF INSECTS DURING 1909. (ORIGINAL.)



FIG. 2.—CAGE BUILT OVER GRAPEVINE IN WHICH THE GENERATIONS OF THE GRAPE-BERRY MOTH WERE REARED DURING 1909. (ORIGINAL.)

OUTDOOR REARING SHELTER AND CAGE USED IN LIFE-HISTORY STUDIES AT NORTH EAST, PA.

TABLE IV.—*Length of incubation of first brood of eggs of the grape-berry moth at North East, Pa., in 1909.*

No. of obser- vation.	Date—		Days of incu- bation.	No. of obser- vation.	Date—		Days of incu- bation.
	Laid.	Hatched.			Laid.	Hatched.	
1.....	June 25	June 29	4	12.....	July 3	July 10	7
2.....	June 26	July 1	5	13.....	do.....	July 11	8
3.....	June 27	July 2	5	14.....	July 5	do.....	6
4.....	June 28	July 4	6	15.....	July 6	July 12	6
5.....	do.....	July 5	7	16.....	July 7	do.....	5
6.....	June 29	do.....	6	17.....	July 8	July 13	5
7.....	do.....	July 6	7	18.....	July 9	do.....	4
8.....	June 30	July 7	7	19.....	July 10	July 16	6
9.....	July 1	July 8	7	20.....	July 12	July 17	5
10.....	July 2	July 9	7	21.....	do.....	July 18	6
11.....	do.....	July 10	8				

Days of incubation:

Average.....	6
Maximum.....	8
Minimum.....	4

Length of feeding period of first-brood larvæ.—The records for the length of the feeding period of the first-brood larvæ are given in Table XI (p. 37), which shows a range from 19 to 33 days and an average of 23.2 days. The small number of observations made was due to the difficulty of securing the deposition of a larger number of eggs from the moths in captivity.

Length of pupal stage of first brood.—Table V gives the time of leaving the fruit of 285 first-brood larvæ and the date of emergence of the moths. The average time for making the cocoon was approximately 2 days. The minimum time covered from leaving of fruit to emergence of moths was 10 days, the average 15.2 days, and the maximum 25 days. Therefore, deducting 2 days spent by the larva in making the cocoon the minimum pupal period was 8 days, the average 13.2 days, and the maximum 23 days.

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TABLE V.—*Time of cocooning and the length of the pupal stage of the first brood of the grape-berry moth at North East Pa., in 1909.*

Number of larvæ.	Larvæ left fruit.	Moths emerged.	Days—		Number of larvæ.	Larvæ left fruit.	Moths emerged.	Days—		
			In co- coon.	Total.				In co- coon.	Total.	
3.....	July 29	Aug. 10	12	36	3.....	Aug. 6	Aug. 24	18	54	
7.....	do.	Aug. 14	16	112	2.....	Aug. 7	Aug. 20	13	26	
2.....	do.	Aug. 13	15	30	1.....	do.	Aug. 21	14	14	
1.....	do.	Aug. 23	25	25	7.....	do.	Aug. 22	15	105	
1.....	July 30	Aug. 9	10	10	1.....	do.	Aug. 23	16	16	
2.....	do.	Aug. 10	11	22	6.....	do.	Aug. 24	17	102	
1.....	do.	Aug. 12	13	13	1.....	do.	Aug. 27	20	20	
4.....	do.	Aug. 13	14	56	1.....	Aug. 8	Aug. 23	15	15	
9.....	do.	Aug. 14	15	135	6.....	do.	Aug. 24	16	96	
2.....	do.	Aug. 15	16	32	17.....	do.	Aug. 25	17	289	
1.....	do.	Aug. 16	17	17	2.....	do.	Aug. 26	18	36	
8.....	July 31	Aug. 14	14	112	1.....	do.	Aug. 27	19	19	
4.....	do.	Aug. 15	15	60	1.....	Aug. 9	Aug. 22	13	13	
1.....	do.	Aug. 16	16	16	5.....	do.	Aug. 25	16	80	
14.....	Aug. 1	Aug. 15	14	196	12.....	do.	Aug. 26	17	204	
9.....	do.	Aug. 16	15	135	2.....	do.	Aug. 27	18	36	
3.....	Aug. 2	Aug. 15	13	39	1.....	Aug. 10	Aug. 22	12	12	
8.....	do.	Aug. 16	14	112	10.....	do.	Aug. 26	16	160	
2.....	do.	Aug. 17	15	30	9.....	do.	Aug. 27	17	153	
1.....	Aug. 3	Aug. 13	10	10	8.....	do.	Aug. 28	18	144	
2.....	do.	Aug. 16	13	26	1.....	do.	Aug. 29	19	19	
13.....	do.	Aug. 17	14	182	1.....	Aug. 11	Aug. 22	11	11	
5.....	do.	Aug. 18	15	75	1.....	do.	Aug. 25	14	14	
3.....	do.	Aug. 19	16	48	2.....	do.	Aug. 26	15	30	
2.....	Aug. 4	Aug. 17	13	26	4.....	do.	Aug. 27	16	64	
3.....	do.	Aug. 18	14	42	1.....	do.	Aug. 28	17	17	
2.....	do.	Aug. 19	15	30	1.....	do.	Aug. 29	18	18	
2.....	do.	Aug. 20	16	32	2.....	Aug. 12	Aug. 27	15	30	
4.....	Aug. 5	Aug. 19	14	56	3.....	do.	Aug. 28	16	48	
5.....	do.	Aug. 20	15	75	3.....	do.	Aug. 29	17	51	
3.....	do.	Aug. 22	17	51	1.....	do.	Sept. 1	20	20	
19.....	Aug. 6	Aug. 19	13	247						
19.....	do.	Aug. 20	14	266	285				4, 334	
4.....	do.	Aug. 22	16	64						

Days.

Average..... 15.2
Maximum..... 25
Minimum..... 10

Time of emergence of first-brood moths.—The material for securing this emergence record of the first-brood moths was taken in part from the large rearing cage in which the eggs had been deposited by earliest emerging moths in the spring. Infested grape berries were removed from the vine in this cage a short time before the larvæ had reached their full growth. The rest of the material was collected from the open vineyard on August 2, 9, and 10. Since larvæ were found in webbed clusters in the open vineyard several days before any larvæ were found in the rearing cage it is probable that a few of the earliest full-grown larvæ of the first brood had escaped from the fruit before it was collected to secure this record, thus making the date of the first-emerging moth in this record a few days later than actually occurred under field conditions. Since the date of the last moth of the spring brood to emerge in our rearing jars was August 4, and the date of the first moth to appear from the first-brood rearing material was July 31, there is evidently an overlapping in the emergence of

moths of the two broods in the field. Table VI contains a record of the emergence of 403 moths, and a glance at the table will show that the maximum number of these first-brood moths emerged from August 14 to August 29. The rate of emergence is graphically shown by the curve in figure 11.

TABLE VI.—*Time of emergence of moths of the first brood (summer moths) of the grape-berry moth at North East, Pa., in 1909.*

Date of emergence.	Number of moths.	Date of emergence.	Number of moths.	Date of emergence.	Number of moths.	Date of emergence.	Number of moths.
July 31	1	Aug. 19	34	Aug. 30	5	Sept. 10	1
Aug. 9	1	20	32	31	13	11	0
10	5	21	1	Sept. 1	4	12	1
11	0	22	17	2	9	13	3
12	9	23	7	3	7	14	0
13	7	24	19	4	4	15	0
14	18	25	23	5	0	Total ..	403
15	28	26	27	6	4		
16	24	27	23	7	2		
17	18	28	27	8	1		
18	10	29	18	9	1		

Oviposition of first-brood moths.—The oviposition records of only a few moths of the first brood were secured and are not numerous enough to give an adequate idea of the length of this period. The

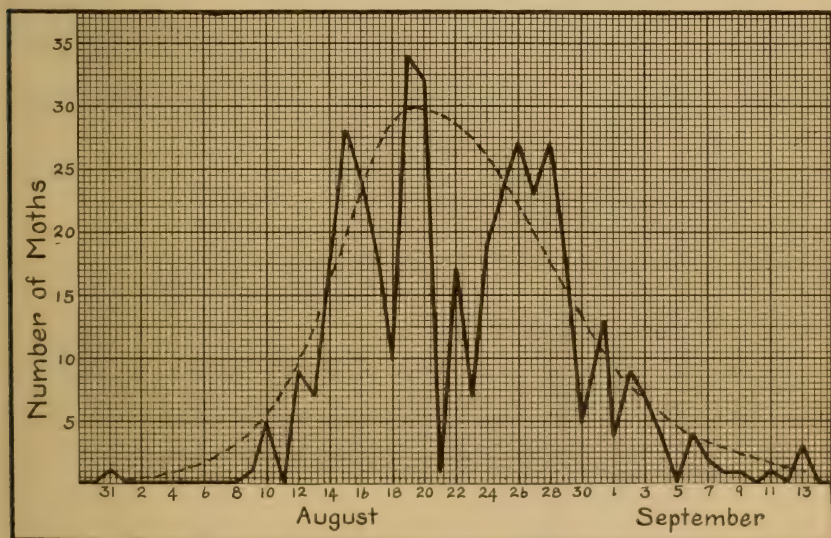


FIG. 11.—Diagram showing time of emergence of the first-brood moths of the grape-berry moth in 1909, at North East, Pa. (Original.)

same difficulty in getting the moths to oviposit freely in confinement was encountered as with the spring-emerging moths. Table VII gives the oviposition of a few individuals of the first brood.

TABLE VII.—*Oviposition of first-brood moths of the grape-berry moth in stock jars at North East, Pa., in 1909.*

No. of stock jar.	Number of moths.	Date of—			Days—		
		Emergence of moths.	First oviposition.	Last oviposition.	Before oviposition.	Of oviposition.	From emergence to last oviposition.
1.....	10	Aug. 18	Aug. 27	Aug. 27	9	1	9
2.....	21	Aug. 19	do	Sept. 8	8	13	20
3.....	21	Aug. 20	do	Aug. 27	7	1	7
4.....	4	Aug. 27	Sept. 5	Sept. 5	9	1	1
Average.....					8.2	4	9.2
Maximum.....					9	13	20
Minimum.....					7	1	1

Hibernation of first-brood pupæ.—Toward the end of July before the eggs of the second brood had been deposited a large number of infested grape berries were collected in order to determine if all of the first brood completed the cycle and emerged as adults, or if some of them passed the winter as pupæ.

Tables VIII and IX give the record for 374 larvæ. Deducting the dead and parasitized individuals from this number, a complete record of 321 specimens was secured. Two hundred and ninety-two adults emerged from July 29 to August 15. After the latter date no adults emerged. Twenty-nine live pupæ failed to transform and hibernated.

TABLE VIII.—*The relative number of transforming and wintering individuals of the first brood of the grape-berry moth, North East, Pa., 1909.*

Number of larvæ.	Date larvæ left berry.	Number of—			
		Moths emerged.	Larvæ hibernating.	Larvæ parasitized.	Dead.
19	July 29	13	0	0	6
20	July 30	20	0	0	0
13	July 31	12	0	0	1
21	Aug. 1	21	0	0	0
16	Aug. 2	14	0	0	2
32	Aug. 3	30	0	1	1
13	Aug. 4	10	0	2	1
18	Aug. 5	12	0	2	4
50	Aug. 6	45	0	1	4
23	Aug. 7	19	0	1	3
36	Aug. 8	30	2	0	4
25	Aug. 9	20	0	1	4
32	Aug. 10	24	1	1	6
15	Aug. 11	10	3	1	1
13	Aug. 12	11	1	1	0
1	Aug. 15	1	0	0	0
10	Aug. 26	0	9	0	1
7	Sept. 11	0	7	0	0
5	Sept. 13	0	4	0	1
3	Sept. 12	0	1	0	2
2	Sept. 18	0	1	0	1

TABLE IX.—*Summary of Table VIII showing number and percentage of first-brood larvæ of the grape-berry moth that transform.*

Observations on—	Number.	Per cent.
Number of larvæ.....	374	100.0
Number of moths emerged.....	292	78.1
Number of hibernating pupæ.....	29	7.8
Number of parasitized larvæ.....	11	2.9
Number of dead individuals.....	42	11.2

Length of life cycle of first generation.—The results of the preceding observations on the separate stages of the grape-berry moth have been summarized in Table X, which shows an average period of 44.2 days for the life cycle of the first generation.

TABLE X.—*Life cycle of the first generation of the grape-berry moth as determined from observations on the separate stages; summaries from the previous tables.*

Stages of development.	Average.	Maximum.	Minimum.
	<i>Days.</i>	<i>Days.</i>	<i>Days.</i>
Egg stage.....	6.0	8	4
Length of feeding.....	23.0	33	19
Making of cocoon.....	15.2	25	10
Pupal stage.....			
Days duration of life cycle.....	44.2	66	33

TABLE XI.—*Life cycle of the first generation of the grape-berry moth, as observed by rearing in 1909 at North East, Pa.*

No.	Dates of—					Days duration—				
	Egg deposition.	Hatching.	Leaving fruit.	Pupa-tion.	Emergence of moths.	Incubation of eggs.	Feeding period of larvæ.	Larvæ making cocoon.	Pupal stage	Life cycle.
1	July 2	July 10	Aug. 5	Aug. 9		8	26	4		
2	July 3	July 11	July 31		Aug. 14	8	20			42
3	July 5	do.	do.		Aug. 18	6	20			44
4	July 7	July 12	do.		Aug. 16	5	19			40
5	do.	do.	Aug. 6	Aug. 7		5	25	1		
6	July 8	July 13	Aug. 4	Aug. 6		5	22	2		
7	do.	do.	Aug. 5	do.	Aug. 19	5	23	1	13	42
8	do.	do.		do.	do.	5				42
9	July 9	do.	Aug. 5	Aug. 6		4	23	1		
10	do.	do.	Aug. 6	Aug. 7		4	24	1		
11	do.	do.	Aug. 15	Aug. 17	Aug. 31	4	33	2	14	53
12	July 10	July 16	Aug. 5	Aug. 8		6	20	3		
Average.....						5.4	23.2	1.9	13.5	43.8
Maximum.....						8	33	3	14	53
Minimum.....						4	19	1	13	40

The average figures in Table X agree closely with the results obtained from the rearings of life-cycle series (Table XI). It will be noted under the life-cycle column that six individuals completed their life cycle the same season, while six pupæ wintered. The shortest

life-cycle period was 40 days, the average length 43.8 days and the longest 53 days. There is a difference of less than half a day in the averages for the two separate rearings.

SECOND GENERATION.

Incubation period of second-brood eggs.—For reasons previously assigned the record of egg laying by the moths in confinement is very scanty. Table XII gives the length of this stage for nine eggs of known origin. The incubation period of these eggs is longer than in the record secured for eggs deposited by the spring-emerging moths. The number of eggs recorded, however, is far too small to admit of generalization on this topic.

TABLE XII.—*Length of incubation of second-brood eggs of the grape-berry moth, North East, Pa., 1909.*

No. of observation.	Date—		Days of incubation.	No. of observation.	Date—		Days of incubation.
	Laid.	Hatched.			Laid.	Hatched.	
1	Aug. 27	Sept. 7	11	6	Sept. 2	Sept. 12	10
2	Aug. 30	Sept. 9	10	7	Sept. 4	Sept. 13	9
3	..do....	Sept. 10	11	8	..do....	Sept. 14	10
4	Aug. 31	Sept. 11	11	9	Sept. 5	..do....	9
5	Sept. 1	..do....	10				

Days of incubation:

Average.....	10.1
Maximum.....	11
Minimum.....	9

Length of feeding period of second-brood larvæ.—Tables XIII–XIV give the feeding period of second-brood larvæ under two entirely different conditions, namely, larvæ reared on green fruit in stock jars under a rearing shelter (Table XIII) and larvæ feeding on fruit growing on a vine (Table XIV) in a large outdoor rearing cage (see Pl. VII, fig. 2).

TABLE XIII.—*Length of the feeding period of the second-brood larvæ of the grape-berry moth under confinement in jars, North East, Pa., 1909.*

No. of observation.	Larvæ hatched.	Larvæ left fruit.	Number of days.	No. of observation.	Larvæ hatched.	Larvæ left fruit.	Number of days.
1	Aug. 27	Oct. 6	40	12	Aug. 30	Oct. 26	57
2	..do....	Oct. 9	43	13	..do....	Nov. 1	63
3	Aug. 29	Oct. 17	49	14	..do....	..do....	63
4	..do....	..do....	49	15	Sept. 11	Nov. 3	53
5	..do....	Oct. 20	52	16	..do....	Oct. 25	44
6	..do....	Oct. 21	53	17	..do....	Nov. 3	53
7	..do....	..do....	53	18	..do....	..do....	53
8	Aug. 30	Oct. 22	53	19	..do....	..do....	53
9	..do....	Oct. 25	56		Average.....		52.6
10	..do....	..do....	56		Maximum.....		63
11	..do....	..do....	56		Minimum.....		40

TABLE XIV.—*Length of the feeding period of second-brood larvæ of the grape-berry moth in fruit on the vines under large outdoor rearing cages, North East, Pa., 1909.*

Number of larvæ.	Larvæ hatched.	Larvæ left fruit.	Number of days.	Number of larvæ.	Larvæ hatched.	Larvæ left fruit.	Number of days.
6	Aug. 25	Sept. 25	31	9	Aug. 25	Oct. 7	43
1	do.....	Sept. 26	32	1	do.....	Oct. 8	44
3	do.....	Sept. 27	33	6	do.....	Oct. 9	45
9	do.....	Sept. 28	34	7	do.....	Oct. 10	46
1	do.....	Sept. 29	35	7	do.....	Oct. 11	47
8	do.....	Oct. 2	38	1	do.....	Oct. 17	53
7	do.....	Oct. 3	39	Average			40.3
7	do.....	Oct. 4	40	Maximum			53
10	do.....	Oct. 5	41	Minimum			31
8	do.....	Oct. 6	42				

The infested grape clusters were removed from the cage just before the larvæ were ready to leave the berries. These larvæ hatched from eggs deposited between August 20 and 25. It was impossible to determine the exact date of hatching of all of the eggs, but only a very small number hatched previous to August 25 and this may account in a measure for the shorter average period of feeding than is recorded for the larvæ from the stock jars. In addition to this all but one of these larvæ had left the fruit previous to the occurrence of a decided drop in temperature between October 12 and 20, whereas only two of the larvæ had emerged from the fruit in the stock jars. Hence, since insect activities were slight during this cold wave the period spent in the fruit by those larvæ which had not escaped previous to its occurrence was abnormally prolonged.

The minimum period spent in fruit by larvæ in the rearing cage was 31 days as against 40 days by those in stock jars; the average 40.3 days as against 52.6 days, and the maximum 53 days as against 63 days.

Date second-brood larvæ leave fruit.—A record was made of the period during which the larvæ leave the berries, with a view to ascertaining whether many of them are likely to be removed from the vineyard when the ripe grapes are being marketed. A large number of larvæ which infested grape clusters were collected from vineyards August 20–24. At this date few if any of the larvæ of the second brood had fully matured. Since the emergence of the two broods of moths overlap it is quite likely that some of the larvæ in this record belong to the first brood. Daily examinations of the collected material were made and the record of the larvæ leaving the fruit is given in Table XV.

TABLE XV.—*Time of second-brood larvæ of the grape-berry moth leaving berries in 1909; from fruit collected in the field, North East, Pa.*

Date of leaving the fruit.	Number of larvæ.	Date of leaving the fruit.	Number of larvæ.	Date of leaving the fruit.	Number of larvæ.	Date of leaving the fruit.	Number of larvæ.
Sept. 22	11	Oct. 6	53	Oct. 20	2	Nov. 3	6
23	21	7	50	21	9	4	0
24	15	8	40	22	5	5	1
25	19	9	38	23	5	6	0
26	8	10	50	24	0	7	1
27	11	11	24	25	7	8	7
28	16	12	14	26	13	9	3
29	21	13	5	27	1	10	0
30	12	14	0	28	0	11	2
Oct. 1	12	15	2	29	4	12	4
2	73	16	1	30	1	13	1
3	39	17	2	31	4	14	2
4	38	18	4	Nov. 1	24		
5	45	19	0	2	19	Total.	745

In all, 745 larvæ emerged. The table shows that 569, or four-fifths of the larvæ, left the fruit in 20 days, from September 22 to October 11, and that the remaining 149, or one-fifth, left the fruit between October 12 and November 14, a period of 34 days, making a total period of 45 days during which second-brood larvæ were leaving the fruit. Since the heavy shipment of Concord grapes does not

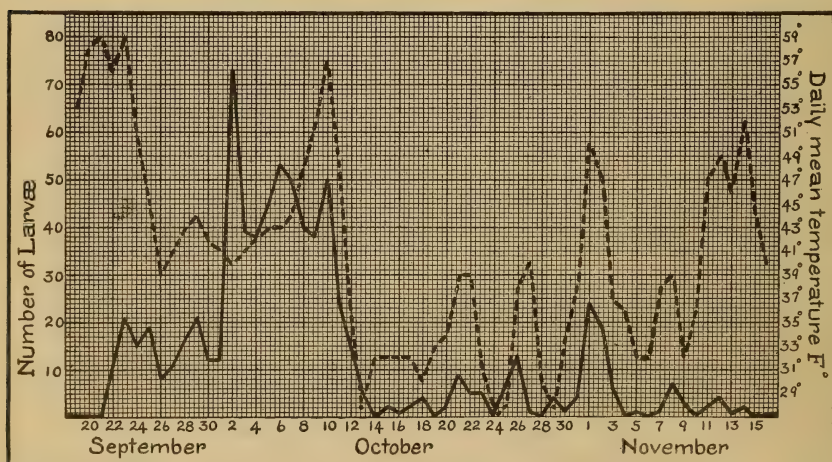


FIG. 12.—Diagram showing time of leaving the grape berries by second-brood larvæ of the grape-berry moth, from fruit collected in the field, North East, Pa., 1909. Daily mean temperature Fahrenheit. (Original.)

occur until October 1, fruit in infested vineyard areas would have to be removed during the first week of the picking season in order to remove many of the larvæ from the vineyard with the crop.

Figure 12 shows the correlation between the fluctuations of temperature and the activity of the mature larvæ of the second brood in leaving the grape berries in the fall of 1909. The dotted line represents the daily mean temperature, and the solid line the rate of emergence of the larvæ from the berries. It will be observed that

there was a period of very low temperature from October 14 to 18, and that this is correlated with an almost complete cessation of emergence of the larvæ. There is no doubt that the abnormally low temperature for this date prolonged the emergence period of the larvæ for the season of 1909.

MISCELLANEOUS REARING RECORDS FOR THE SEASONS OF 1907 AND 1908.

The rearing records for the seasons of 1907 and 1908 are less extensive and not so complete as those made a year later, but they agree in general with the more complete records of 1909. Table XVI gives the emergence record of 24 moths of the spring brood for the season of 1907.

TABLE XVI.—*Time of emergence of moths of the grape-berry moth in the spring of 1907.*

Date of emergence.	Number of moths.	Date of emergence.	Number of moths.	Date of emergence.	Number of moths.	Date of emergence.	Number of moths.
June 21	1	June 25	4	June 30	1	July 6	1
22	1	26	3	July 2	1	7	1
23	1	28	3	3	1	10	1
24	3	29	1	4	1		

No record of egg deposition by the spring brood of moths was secured for the season of 1907, nor was a record made of the length of the larval stage for the first brood.

The complete record of two pupæ of the first brood was secured during 1907 which covered a period of 13 days for this stage, and a record of one pupa in 1908 which covered a period of 12 days. These records are shorter than the average length of this stage for a large number of specimens observed in 1909 (see Table V, which shows a period of 15.2 days).

An emergence record of 695 moths of the first brood was secured during the season of 1907. (See Table XVII.) Unfortunately some of the earliest maturing larvæ had escaped from the infested fruit before it was collected. Hence some of the earliest emerging moths are not shown, since the first emergence in this record is dated August 17.

TABLE XVII.—*Time of emergence of first-brood moths of the grape-berry moth. North East, Pa., 1907.*

Date of emergence.	Number of moths.	Date of emergence.	Number of moths.	Date of emergence.	Number of moths.	Date of emergence.	Number of moths.
Aug. 17	56	Aug. 26	105	Sept. 1	22	Sept. 9	39
19	5	27	33	2	13	11	19
20	29	28	36	3	7	14	3
21	70	29	60	4	11		
22	34	30	36	5	22	Total .	695
24	57	31	28				

Figure 13 gives a graphic representation of the rate of emergence of the moths of the first brood for the season of 1907.

The most extensive record of the egg stage of the second brood was secured in the season of 1907. Table XVIII gives the length of this stage for 35 eggs, which shows an average of 6.5 days, the

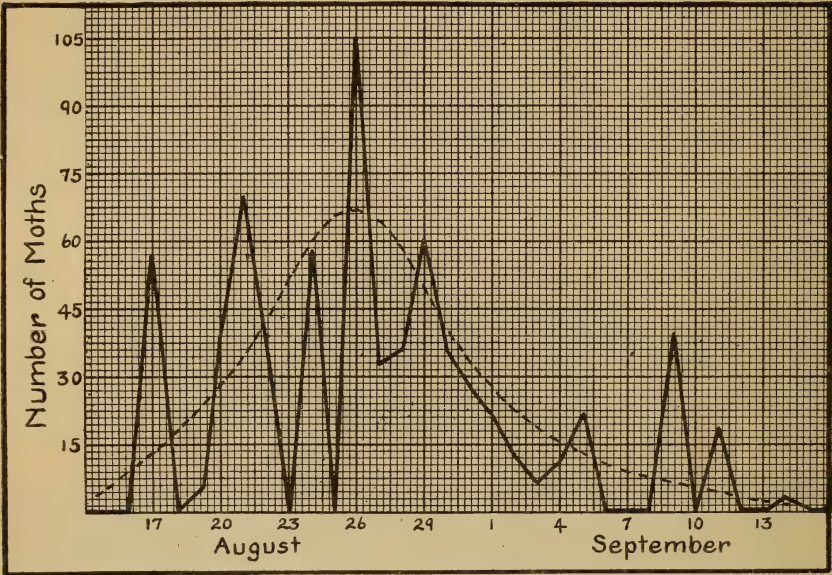


FIG. 13.—Diagram showing the time of emergence of the first-brood moths of the grape-berry moth in 1907, at North East, Pa. (Original.)

minimum being 5 days and the maximum 9 days. This record shows a shorter period than that secured for a smaller number of eggs in 1909 (see Table XII, which shows an average of 10.1 days, a minimum of 9 days, and a maximum of 11 days).

TABLE XVIII.—Length of incubation of second-brood eggs of the grape-berry moth, North East, Pa., 1907.

No. of observation.	Date—		Days of incubation.	No. of observation.	Date—		Days of incubation.	No. of observation.	Date—		Days of incubation.
	Laid.	Hatched.			Laid.	Hatched.			Laid.	Hatched.	
1	Aug. 31	Sept. 6	6	14	Sept. 1	Sept. 9	8	27	Sept. 10	Sept. 16	6
2	do.	do.	6	15	do.	do.	8	28	do.	Sept. 17	7
3	do.	do.	6	16	do.	do.	8	29	Sept. 11	Sept. 16	5
4	do.	do.	6	17	do.	do.	8	30	do.	Sept. 17	6
5	do.	Sept. 7	7	18	Sept. 10	Sept. 16	6	31	do.	do.	6
6	do.	do.	7	19	do.	do.	6	32	Sept. 12	do.	5
7	do.	do.	7	20	do.	do.	6	33	do.	do.	5
8	do.	do.	7	21	do.	do.	6	34	do.	do.	5
9	do.	do.	7	22	do.	do.	6	35	do.	Sept. 18	6
10	do.	Sept. 8	8	23	do.	do.	6				
11	do.	do.	8	24	do.	do.	6				
12	do.	do.	8	25	do.	do.	6				
13	Sept. 1	Sept. 9	8	26	do.	do.	6				
									Average		6.5
									Maximum		8
									Minimum		5

Table XIX gives the emergence record of 279 moths of the spring brood for the season of 1908. There is a variation of several days in the dates of the maximum emergence of the moths for the three seasons, the maximum emergence being nearly a week earlier in 1908 than in 1907 and 1909. In each instance, however, the period of maximum emergence of the moths coincided quite closely with the period of full bloom of the grape.

TABLE XIX.—*Time of emergence of moths of the grape-berry moth in the spring of 1908, North East, Pa.*

Date of emergence.	Number of moths.	Date of emergence.	Number of moths.	Date of emergence.	Number of moths.	Date of emergence.	Number of moths.
June 1	6	June 19	15	July 3	3	July 15	1
June 7	5	June 20	15	July 5	1	July 16	1
June 8	17	June 21	1	July 6	2	July 17	1
June 9	7	June 22	7	July 8	1	July 19	1
June 10	12	June 23	8	July 9	1	July 20	2
June 12	16	June 24	9	July 10	1	July 22	1
June 13	30	June 25	4	July 11	1	July 23	2
June 15	14	June 26	3	July 12	1	July 25	1
June 16	22	June 29	11	July 13	1		
June 17	17	July 1	1	July 14	4	Total	279
June 18	33						

Figure 14 gives a graphic description of the rate of emergence of the spring brood of moths for 1908, showing that the maximum number of moths emerged after June 13—about the date that grapes normally commence to blossom.

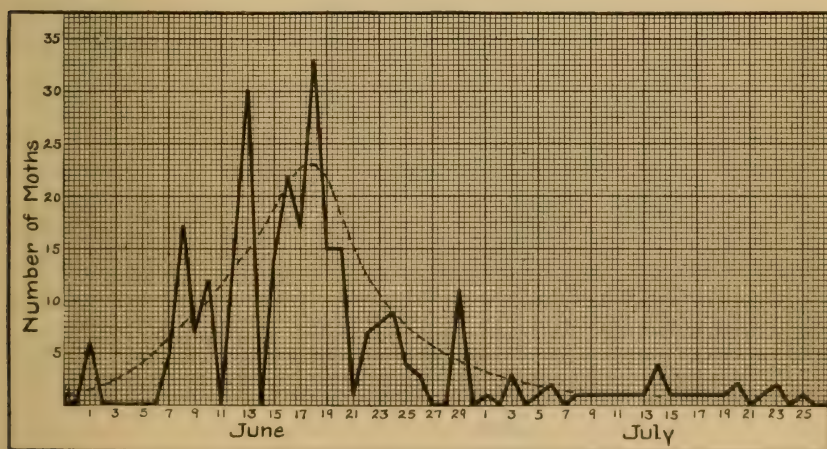


FIG. 14.—Diagram showing the time of emergence of the spring-brood moths of the grape-berry moth in 1908, at North East, Pa. (Original.)

The first record of oviposition in 1908 was made of eggs found in very small berries in rearing cages June 17. No record of the egg stage of the first brood was secured, on account of great difficulty in getting moths to oviposit in confinement. The larval period

of one specimen of the first brood in 1908 was secured. This larva hatched June 20. It emerged from fruit and started to make its pupal case July 10, and had transformed to pupa by July 12, making the larval stage 22 days in length. This period coincides quite closely with the average larval period secured for several larvæ of the first brood during the season of 1909, which was 21.25 days.

The earliest record of emergence of first-brood moths was made on July 13 from a pupa found July 1 on a leaf in the rearing cage in 1908. This is 10 days earlier than the record for other moths from the same source (see Table XX). The emergence record in this table is doubtless somewhat abnormally early, owing to the fact that the temperature in the rearing cage was several degrees higher than outside.

TABLE XX.—*Time of emergence of first-brood moths of the grape-berry moth, North East, Pa., 1908.*

Date of emergence.	Number of moths.	Date of emergence.	Number of moths.	Date of emergence.	Number of moths.	Date of emergence.	Number of moths.
July 23	3	July 26	26	July 29	4	Aug. 1	1
July 24	4	July 27	31	July 30	2		
July 25	8	July 28	9	July 31	3	Total.	91

SUMMARY OF LIFE-HISTORY STUDIES OF THE GRAPE-BERRY MOTH.

Life-history studies of this pest at North East, Pa., during the seasons of 1907, 1908, and 1909 indicate that there is only one full brood of larvæ and a partial second brood each year in the vineyards of the Lake Erie Valley. The partial second brood of larvæ, however, is larger in numbers than the full first brood, probably on account of the large number of fatalities that occur among the pupæ during the winter season which tends materially to lessen the number of moths that emerge in the spring. The moths from overwintering pupæ commence to emerge about June 1. (See fig. 15, with curve showing length of the various stages of the grape-berry moth for the season of 1909.) Less than 25 per cent of these spring-emerging moths appear before the grape is in full bloom. The total emergence period of the spring moths is about 60 days. As the period of maximum emergence is from June 10 to July 10, it overlaps into the emergence period of the first brood. About 4 to 6 days elapse between the emergence of the moths and the deposition of eggs. The egg stage of the first brood covers about 6 days. The larval period covers about 23 days and the pupal stage about 13 days. A small percentage of the pupæ of this first brood pass the winter. The moths of the first brood commence to emerge during the latter part of July, the maximum number emerging from about August 10 to September 1. The period of incubation of the second-brood eggs is a little longer than

that of the first brood. (See Tables IV and XII.) The larval stage of this brood is also longer than that of the first brood, the average being 22 days for the first brood of larvæ as against 40 days for the larvæ of the second brood. The larvæ of the second brood commence to leave the fruit about the middle of September. The maximum number of larvæ leave the fruit during the last week in September and the first 10 days in October. By October 15 the number of larvæ found in the fruit upon the vines is very small. By this date practically all of them have dropped to the ground and formed pupal cases on the small percentage of grape leaves that have fallen prematurely from the vines. Rarely is a pupal case of this second brood found on the leaves attached to the vines. On

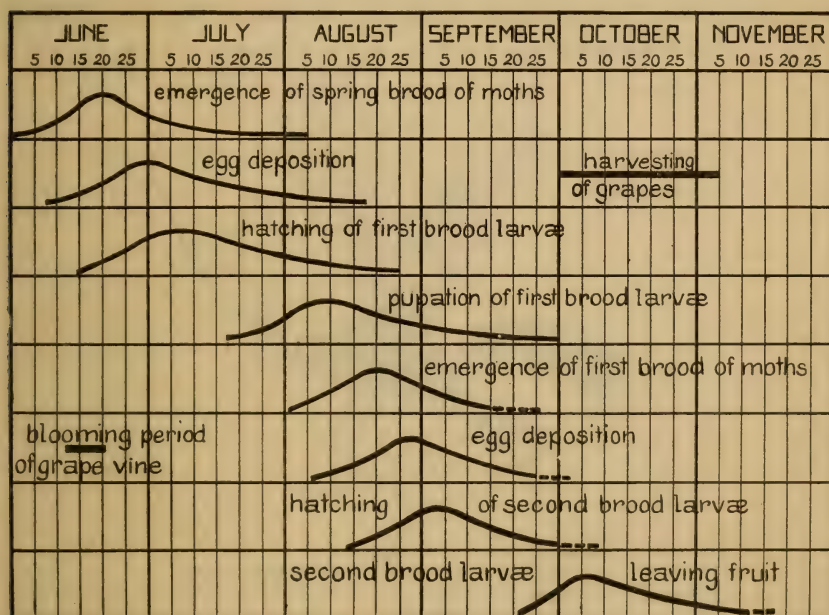


FIG. 15.—Seasonal history of the grape-berry moth as observed in 1909, at North East, Pa. (Original.)

the moist leaves on the ground beneath the vines the second-brood arvæ and also a small percentage of the first brood make their cocoons and pass the winter as pupæ.

PARASITIC ENEMIES.

Detailed studies of the habits and life history of the grape-berry moth during the past few years have shown that this insect is beset with a large number of hymenopterous parasites. Previous to the study of the habits of this pest made by Prof. M. V. Slingerland in the vineyards of Chautauqua County, N. Y., the only record of attack by parasites found in the literature on this subject is made by Dr. C. V. Riley in 1869. Two maggots were found by him destroying

the larvæ of the grape-berry moth, but he failed to rear the adult parasites from them.

During his studies of this insect covering the seasons of 1903 and 1904, Prof. Slingerland reared six different kinds of parasites of the grape-berry moth, which he considered an unusually large number. Four of these were ichneumonids and two were braconids. These rearings by Prof. Slingerland are quoted as follows:¹

Bracon scrutator Say. (Boston Journ. Nat. Hist., I, 254). The maggot of this little Braconid parasite seems to feed externally on the nearly full-grown caterpillars of the second brood at work in the green fruit in August. Their little, white cocoons are spun in the infested berries. The adults emerged in about two weeks on the following dates: Aug. 28, Sept. 1, 4, and 10.

Bathymetis sp. near *terminalis* Ashm. We reared two females of this comparatively large parasite from hibernated pupæ on May 31. The grape-berry moth caterpillar



FIG. 16.—*Thymaris slingerlandana*, a common parasite of the grape-berry moth. Enlarged. (After Slingerland.)

had pupated and the parasite's cocoon filled that of its host. Dr. Ashmead reports our specimens as probably undescribed, but possibly *terminalis*, which was described from a male only.

Glypta animosa Cress. (Trans. Am. Ent. Soc., III, 154). One specimen of this Ichneumon emerged from an over-wintered cocoon on June 4. It spun a very thin cocoon and had evidently killed the caterpillar, as no trace of a pupa was found. The recorded hosts of this parasite are *Pædisca scudderiana*, two other Tortricids and a Pyralid.

Glypta vulgaris Cress. (Trans. Am. Ent. Soc., III, 157). Two specimens of this common parasite emerged on August 25 and 27 from thin, white cocoons nearly filling their host's cocoon in a wild grape. Like *Glypta animosa*, this species evidently kills the caterpillar, but it works on the summer brood. It is also parasitic on a species of *Gelechia* and on a Pyralid (*Margaronia quadristigmatis*).

¹ Bul. 223, Cornell Univ. Agr. Exp. Sta., pp. 52-53, 1904.

Urogaster [= *Apanteles*] *canarsiae* Ashm. (Ent. Soc. Wash., IV, 127, with figure). Found the cocoons of this probable parasite in the webbed blossoms where grape-berry moth caterpillars had worked. Two specimens emerged on July 3 and 7. Its other known host is the Pyralid (*Canarsia hammondi*).

Thymaris slingerlandana Ashm. [fig. 16] (Can. Ent., XXXVI, Nov., p. 333). From August 15 to 27, we reared 17 specimens of this little black Ichneumon with orange-colored, light yellow-banded legs from the cocoons of the grape-berry moths working in both wild and cultivated grapes. Its cocoon occupies about half the space inside the host's cocoon, and evidently the caterpillar was its victim.

In the miscellaneous rearings of the different stages of the grape-berry moth made at the field laboratory of the Bureau of Entomology at North East, Pa., from 1906 to 1911, in connection with life-history studies, together with parasitized specimens observed and collected in the vineyards, 12 additional hymenopterous parasites of different species have been recorded as preying upon this insect. This makes a total list of 17 different parasites known to prey upon this vineyard pest in the Lake Erie Valley at some stage or other of its life cycle. This is a long list of natural enemies for an insect. These parasites are doubtless an important factor in reducing the numbers of the grape-berry moth and their occurrence may explain to some extent the fluctuations in its numbers which occur from year to year.

In the rearing work conducted at North East, Pa., all of the adult parasites emerged from jars containing either larvæ or pupæ of the grape-berry moth during the period between July 12 and September 14. No parasites were collected in the early spring from overwintering cocoons, although a large amount of this material was carried over the winter of 1908 for the purpose of making life-history studies during the season of 1909. This would indicate that parasitism is most active upon the developing first brood of larvæ and pupæ about the period at which this brood exists in the greatest numbers. It would seem, therefore, that the great activity of these parasites during this period must be an important factor in curtailing the second brood of grape-berry moth larvæ that is so destructive to the grape berries at the approach of the ripening season.

Five of the parasites reared were braconids, seven were ichneumonids, all reared from larvæ and pupæ, and one, a chalcidid, reared from the eggs of the grape-berry moth. All of the parasites with the exception of the egg parasites were determined by Mr. H. L. Viereck, of the Bureau of Entomology. Their names are given in Table XXI, which also gives the date of their emergence, the stage of the host, the number reared, and the other host insects from which they have been previously recorded.

TABLE XXI.—*Parasites reared from the grape-berry moth (Polycrosis viteana) feeding upon the fruit of wild and cultivated grapes at North East, Pa., 1906-1911.*

Family.	Date of emergence.	Stage of host.	Number of specimens reared.	Previously recorded hosts.
BRACONIDÆ.				
<i>Microbracon mellitor</i> Say.....	Aug. 6-19, 1909....	Larva....	15	Many species of Coleoptera and Lepidoptera.
<i>Microbracon dorsator</i> Say.....	Aug. 3-Sept. 1, 1911....	...do....	9	Do.
<i>Apanteles</i> sp.....	Aug. 12, 1911.....	...do....	1	No record.
<i>Ascogaster carpocapsæ</i> Vier.....	Aug. 14, 1911.....	Pupa....	4	<i>Carpocapsa pomonella</i> .
<i>Meteorus</i> sp.....	Aug. 9, 1909.....	Larva or pupa.	1	No record.
ICHNEUMONIDÆ.				
<i>Phytodietus</i> sp.....	July 13, 1906.....	Larva....	1	Do.
<i>Epiurus indagator</i> var. <i>nigrifrons</i> Vier.	Aug. 5, 1911.....	...do....	2	Do.
<i>Orthizema</i> sp.....	July 13, 1908.....	...do....	1	Do.
	Sept. 13, 1907.....	...do....	2	
<i>Omorgus nolæ</i> Ashm. race.....	Aug. 16-22, 1909.....	...do....	2	<i>Nola</i> sp., a pyralid
<i>Diocetes oblitteratus</i> Cress.....	July 13, 1906.....	Pupa....	1	<i>Gelechia rubidella</i> .
<i>Diocetes oblitteratus</i> Cress.....	July 21, 1907.....	...do....	2	Do.
<i>Diocetes oblitteratus</i> Cress.....	July 22, 1908.....	...do....	1	
<i>Diocetes oblitteratus</i> Cress.....	Aug. 2-27, 1909.....	...do....	27	Do.
<i>Diocetes oblitteratus</i> Cress.....	Aug. 2-27, 1911.....	...do....	21	Do.
<i>Ameloctonus</i> sp.....	Aug. 24, 1909.....	...do....	3	No record.
<i>Itoplectis conquisitor</i> Say.....	Aug. 3, 1911.....	...do....	2	Many species of tortricids, noctuids, bombycids, and tineids.

In glancing over this table it will be observed that the parasite reared in greatest numbers from the grape-berry moth was *Diocetes oblitteratus* Cress. Mr. Viereck states that the supposedly new species reared by Prof. Slingerland in 1904 and named by Dr. William H. Ashmead¹ as *Thymaris slingerlandana* Ashm. (see fig. 16) is the same as *Diocetes oblitteratus* Cress. The largest number of parasite specimens reared by Prof. Slingerland belonged to this species; hence it is very probable that it is quite widely disseminated throughout the vineyards of the Chautauqua County grape belt wherever the grape-berry moth abounds, and is perhaps the most effective enemy of the grape-berry moth of all of the parasites mentioned in this list.

In addition to the parasites previously mentioned as attacking the larvæ and pupæ, on September 7, 1906, a large number of parasitized eggs of the grape-berry moth were found in a badly infested portion of the vineyard of Mr. W. S. Wheeler at North East, Pa. A number of adults were reared from these parasitized eggs and later identified by Dr. Howard as *Trichogramma pretiosa* Riley. This is the first record of parasitized eggs of this insect that has come to our notice, and it is the only instance in which this condition has been observed during this investigation.

¹ Can. Ent., vol. 36, pp. 333-334, November, 1904.

DEGREE OF VINEYARD INFESTATION IN ERIE COUNTY, PA.

The infestation of vineyards by this pest is by no means general. It frequently happens that serious infestation will be confined to one or two rows along the edge of a vineyard or running in for a few vines at the end of a number of rows, or again, in an irregular patch at the corner of a vineyard. Usually such areas of very serious infestation are adjoining hedgerows, fences, or bordering rough lands which admit of the accumulation of leaves and trash. On the other hand, the worst infestation over a large area coming under our observation was in a vineyard which was surrounded by neither hedges nor ditches, was a considerable distance from woodlots or rough land, and was subject to clean culture and excellent care. Again, it is not unusual to find a vineyard portions of which have been badly infested for a number of seasons but adjacent vineyards comparatively free from infestation. Because of this seemingly erratic infestation it is exceedingly difficult either to estimate the actual damage wrought by the pest or to secure reliable results for comparison as to the amount of benefit from remedial treatment. Another result of this erratic infestation is that the vineyardist will minimize the extent of the injury or even entirely overlook it until picking time, when he is astonished to discover the large amount of damage that has been done. When this abundant evidence of injury is brought so clearly to his attention at picking time he is likely to make a vow to take some steps toward the eradication of the pest next season, but only too often, unless the first brood is extremely abundant, the period for effective treatment is again permitted to slip past and the extent of injury at picking time is likely to be the same as in previous years. An additional result of this somewhat restricted and local infestation is that methods of control of the pest are not so freely discussed among the vineyardists and there is not the impetus of a general effort to effect its control that there is in the endeavor to combat an insect whose injury is more apparent and widespread, as in the case of the grape rootworm and the grape leafhopper.

The statements dealing with the destructiveness of this insect in the preceding paragraphs apply to the depredations of the pest in the vineyards of the Lake Erie grape belt, where local conditions have been studied closely for several seasons. In the township of North East, Pa., there is an area stretching east of the town to the New York State line and lying south of the Lake Shore Railroad in which are located the vineyards most heavily infested by the grape-berry moth in this region. In the summer of 1906 one large vineyard was visited in this area in which the infestation was quite general and on limited portions of it the fruit was almost unmarketable.

The infested clusters shown in Plate VI, figures 1-2, were taken from this vineyard. In not all of the vineyards in this area is serious infestation so general. In some of them serious infestation is quite local and in others the injury is almost negligible. Outside of this area infestation in vineyards in Erie County, Pa., is more or less local. Yet the insect is always present in sufficient numbers to become a menace at any time that natural conditions favor its rapid increase, and at the present time the insect is responsible for a greater shrinkage in crop yield than most vineyardists are aware.

REMEDIAL MEASURES.

Several methods for the control of the larvæ of the grape-berry moth have been recommended, namely, the destruction of fallen leaves, plowing the vineyard late in the fall or very early in the spring, bagging the clusters, picking the infested berries, removal of infested berries from the vineyard during the harvesting season, and the use of poison sprays.

THE DESTRUCTION OF FALLEN LEAVES.

Since the larvæ of the second brood on leaving the ripening fruit make their cocoons upon the leaves of the grapevine, the destruction of the fallen leaves has been frequently recommended as a means of control. Until within recent years, however, it was not known that practically all of the overwintering larvæ, on leaving the fruit, instead of forming their cocoons upon the grape leaves attached to the vines, drop to the ground and form their hibernating cocoons on the small percentage of prematurely fallen leaves. Observations on the hibernation habits of this insect in infested vineyards at North East, Pa., in the fall of 1906, showed that practically all of the larvæ had emerged from the fruit by the end of the first week in October and that all of the larvæ and pupæ found at that date were in the cocoons made on leaves upon the ground directly beneath the trellis. In practically all cases the leaves upon which these cocoons were made were in close contact with the soil and in a more or less sodden condition, either from moisture absorbed from the soil or as a result of the fall rains. Many leaves bearing cocoons were plastered to the ground as a result of beating rains and even at this early date were in such a state of semidecay that in attempting to gather the leaves they sometimes fell to pieces in much the same manner that a rainsoaked sheet of newspaper will do under the same conditions.

Although hundreds of cocoons were found on these moist leaves upon the ground only one cocoon was found upon the leaves still attached to the vines, and this was imperfectly formed. Practically all of the fruit on the vines examined during the first week in October had been recently infested and was still hanging upon the vines in close contact with the foliage. These observations confirm those

made by Prof. H. A. Gossard in Ohio during the same season. Searches in badly infested vineyards every season since 1906 have shown a similar condition. This habit of the larvæ may be due to the fact that at this season the leaves upon the vines are somewhat withered and brittle. Hence it would appear to be more difficult for the larvæ to fold the flap of the portion of the leaf cut out for making the cocoon, whereas, when the leaves have fallen to the ground and have absorbed moisture from the soil they are less brittle and the flap can be folded much more readily. Whether this is the true cause of the larvæ seeking the leaves on the ground upon which to form their overwintering cocoons or not the fact that they do so has an important bearing upon the practice of destroying fallen leaves as a means of destroying the overwintering pupæ. Since most of the cocoons are made upon a small number of leaves which are stuck more or less firmly to the ground there is little likelihood that many of them will be blown into piles in the corners of vineyards or into hedgerows as has been supposed. Unless these infested leaves are gathered carefully before the period of soaking rains during the late fall and winter they are likely to fall apart and leave the cocoons containing the pupæ in the vineyard. Perhaps an attempt to gather these infested leaves from the ground beneath the trellis during the middle or latter part of October, before the remainder of the leaves have fallen from the vines, would prove more effective than to try to destroy all of the leaves at a later date. There is no doubt that large numbers of pupæ can be collected in this way over limited areas where the infestation is heavy. Unfortunately, however, the vineyardist is too busily engaged in harvesting his grape crop at this time to adopt this method of control.

PLOWING IN LATE FALL OR EARLY SPRING.

Since it is evident that few of the infested leaves are likely to be removed by the winds from the ground beneath the trellis it is quite possible that large numbers of them could be destroyed by plowing the badly infested portion of the vineyards immediately after the crop of grapes is harvested and before the rest of the leaves have fallen from the vines. Plowing at this time would be more likely to insure the covering of the infested leaves than if all of the leaves had fallen, for then the loose leaves would be likely to drive ahead of the plow and force some of the infested leaves to the surface.

Many vineyardists object to fall plowing of vineyards, and, where it is impracticable, early spring plowing is suggested. Care should be taken to throw the soil well under the trellis so that all of the leaves may be covered. Since only a small percentage of the moths emerge before June 1, plowing up to the trellis during the month of May would doubtless cover many of the pupæ.

BAGGING THE CLUSTERS.

In some parts of New York State the fruit on many acres of Niagara grapevines is protected by inclosing each cluster in a paper bag immediately after blossoming. The bagging of clusters of this variety is done primarily for protection against rot. This method of control, however, involves considerable expense and while very effective can not be employed as a means of protection except on choice table varieties, and hence will not appeal to the large producers of grapes for wine or grape-juice purposes.

HAND PICKING INFESTED BERRIES.

By hand picking the infested berries from the clusters in July and early August the size of the second brood may be greatly reduced. The infested green berries are made conspicuous by the presence of a purple spot at the point of entrance of the larvæ. Sometimes the berry cracks open and again several small berries may be tied together by a silken web (see Pl. V, fig. 2). Before the berries in the cluster are large enough to touch each other the infested berries may be readily discerned, but at a later date it is necessary either to handle each cluster or to examine the fruit from both sides of the trellis. The infested berries collected in this way should be removed from the vineyard and the larvæ destroyed. This may be done by immersing the berries in a kettle of boiling water or burying them beneath several inches of soil.

REMOVAL OF "TRIMMINGS."

During the past few years it has become a common practice to pick and pack the fruit in baskets in the vineyard. In this case the "wormy" berries are removed from the clusters and allowed to fall to the ground and thus the larvæ infesting them remain in the vineyard to infest the crop during the next season. A better method which is practiced by some vineyardists is to have each picker carry an extra basket into which these infested "trimmings" can be placed and be removed from the vineyard and destroyed. If the badly infested portions of vineyards are harvested at the very opening of the picking season many larvæ can be destroyed in this way. At a later date in the harvesting season this removal of the worm-injured berries from the vineyard will not be very effective, for, as previously explained, practically all of the larvæ have then left the fruit.

EXPERIMENTS WITH POISON SPRAYS.

VINEYARD EXPERIMENTS WITH POISON SPRAYS IN 1907.

In the spring of 1907 an experiment was undertaken in the vineyard of Mr. W. S. Wheeler at North East, Pa. (see fig. 17). In 1906 and for several seasons previous the fruit in sections of the vineyard in which this experiment was conducted had been very badly infested by this insect.

The sections were laid off in seven plats of approximately 1 acre each. There were five rows of vines in each plat. (See plan of plat arrangement, fig. 18; dotted lines in figure indicate divisions of plats.)

The insecticides in all cases were applied with Bordeaux mixture since it is desirable to use this fungicide at the time the applications



FIG. 17.—Vineyard in which poison-spray experiments were conducted against larvæ of the grape-berry moth during the seasons of 1907, 1908, and 1909; vineyard of Mr. W. S. Wheeler, North East, Pa. (Original.)

are made against the larvæ of the grape-berry moth, to control fungous diseases, such as black rot and mildew. In all cases where arsenate of lead was used the Bordeaux formula was 5 pounds of lime and 5 pounds of copper sulphate to 50 gallons of water. Where arsenite of lime was used with the Bordeaux an additional pound of lime was used to counteract any free arsenic which might be present.

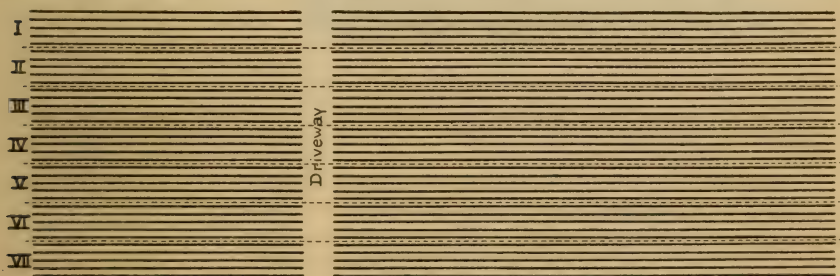


FIG. 18.—Plat arrangement of poison-spraying experiments against the larvæ of the grape-berry moth in the vineyard of Mr. W. S. Wheeler, North East, Pa., 1907. (Original.)

A gasoline-engine vineyard sprayer outfit (fig. 19) was used for making the application.

The spray was applied to the vines from the machine by means of a fixed-nozzle arrangement (see fig. 19). To a vertical rod on both sides of the back end of the machine two short spurs of $\frac{1}{4}$ -inch pipe are attached. Each spur carries a large nozzle of the cyclone type from which the spray is discharged into the side of the vine on the trellis.

A third and upper nozzle is mounted on a longer spur which projects over the trellis. This nozzle is directed downward, throwing the

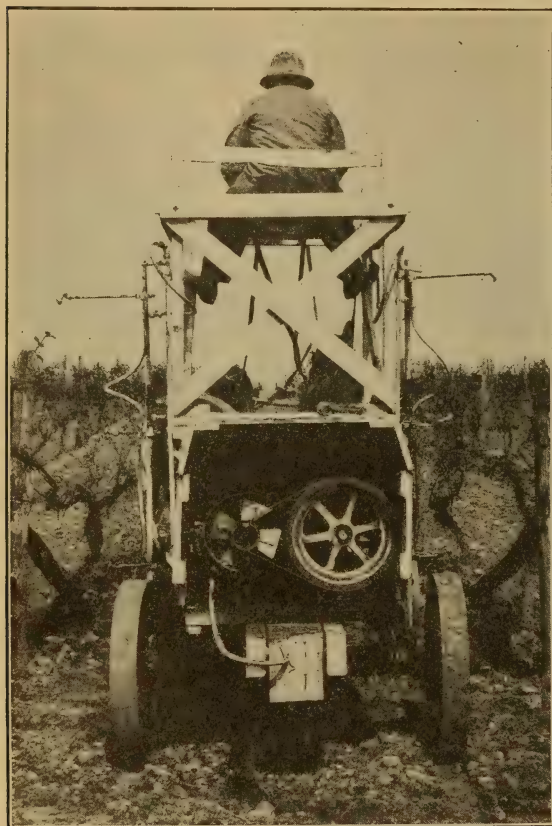


FIG. 19.—Gasoline-engine sprayer outfit used in vineyard experiments against the larvæ of the grape-berry moth in the vineyard of Mr. W. S. Wheeler, North East, Pa., 1907, 1908, and 1909. (Original.)

spray upon the top-most growth on the trellis. Such a machine carrying a pressure of 100 pounds and over will force the spray into the vines on the trellis and cover quite thoroughly all of the foliage and fruit clusters, especially during the early part of the season before the foliage has become dense and before the berries in the cluster have become so large that they touch each other.

In this experiment the team was driven slowly down each row so that the vines were sprayed from both sides of the trellis. A pressure of about 100 pounds was maintained and about 100 gallons of spray were applied per acre.

Table XXII gives the spray treatment applied to each plat and also dates of application.

TABLE XXII.—*Spray formulas and dates of application against larvæ of the grape-berry moth. Vineyard of Mr. W. S. Wheeler, North East, Pa., 1907.*

Plat No.	Spray formula.	Number of spray applications.	Date of application.
I.	Three pounds arsenate of lead to 50 gallons of Bordeaux mixture	3	June 19, July 8, 27.
II.	Three pounds arsenate of lead and 2 pounds resin-fish-oil soap to 50 gallons of Bordeaux mixture.	3	Do.
III.	One quart arsenite of lime, Kedzie's formula, and 2 pounds resin-fish-oil soap to 50 gallons of Bordeaux mixture.	3	Do.
IV.	One quart arsenite of lime, Kedzie's formula, to 50 gallons of Bordeaux mixture.	3	Do.
V.	One quart arsenite of lime, Kedzie's formula, and 2 pounds resin-fish-oil soap to 50 gallons of Bordeaux mixture.	2	July 9, 27.
VI.	Unsprayed.	—	—
VII.	Three pounds arsenate of lead and 2 pounds resin-fish-oil soap to 50 gallons of Bordeaux mixture.	2	Do.

The variations in the formulas were made to ascertain, if possible, the value of arsenate of lead as against arsenite of lime in the control of this insect. The resin-fish-oil was added on some plats and withheld on others to determine its value as an adhesive in making the spray stick to the grape berries. The variation in number of applications was made to ascertain if applications made before the blossoming of the grape were of greater value than those made after blossoming. The application on June 19 was made when the blossom clusters were well developed, but a few days before actual blossoming (see fig. 20). The application on July 8 was made after blossoming when the berries were about the size of buckshot (Pl. V, fig. 1). At this stage of development the berries stand some distance apart and the spray can be forced through the cluster, so as to cover all of the berries. The application July 27 was made for the purpose of covering the berries to protect them from the entrance of larvæ of the second brood.



FIG. 20.—Stage of development of grape blossom cluster at which poison-spray application should be made against early hatching larvæ of the grape-berry moth which infest the blossom clusters. (Original.)

In all of these applications the work was quite thorough, and with the exception of the third application most of the clusters were well covered by the spray. When the third application was made the foliage had become rather dense, making it more difficult to reach the clusters, and at the same time the berries had increased in size, forming a somewhat compact cluster. These conditions made it increasingly difficult to force the spray in among the berries. Furthermore, too much poison forced into the clusters in this condition is undesirable, since some of it is likely to be present in the cluster when the fruit is ripe and thus render it undesirable for table use.

During the season four counts were made of infested berries on 25 vines in all of the plats. Table XXIII shows the increase in infestation:

TABLE XXIII.—*Progress of infestation of fruit by larvæ of the grape-berry moth in experimental plats. Vineyard of Mr. W. S. Wheeler, North East, Pa., 1907.*

FIRST COUNT OF INFESTED BERRIES MADE JULY 24.

Plat No.	Date of spray application.	Number of applications.	Spray formula.	Number of vines examined.	Total number of clusters.	Average number of berries per cluster.	Number of infested berries.	Total number of berries counted.	Percentage of berries infested.
I.	June 19, July 8, 27.	3	5-5-3-50.....	25	997	36	205	35,892	0.45
II.	do.....	3	5-5-3-2-50.....	25	853	36	83	30,708	.27
III.	do.....	3	5-6-1 qt.-2-50.....	25	842	36	113	30,312	.37
IV.	July 9, 27.....	3	5-6-1 qt.-50.....	25	835	36	131	30,060	.43
V.	do.....	2	5-6-1 qt.-2-50.....	25	744	36	172	26,784	.64
VI.	Unsprayed.....	None.	None.....	25	890	36	317	32,040	.98
VII.	July 9, 27.....	2	5-5-3-2-50.....	25	1,204	36	126	43,344	.29

SECOND COUNT OF INFESTED BERRIES MADE AUG. 29.

I.	June 19, July 8, 27.	3	5-5-3-50.....	25	997	36	662	35,892	1.84
II.	do.....	3	5-5-3-2-50.....	25	853	36	337	30,708	1.09
III.	do.....	3	5-6-1 qt.-2-50.....	25	842	36	432	30,312	1.09
IV.	do.....	3	5-6-1 qt.-50.....	25	835	36	330	30,060	1.09
V.	July 9, 27.....	2	5-6-1 qt.-2-50.....	25	744	36	419	26,784	1.56
VI.	Unsprayed.....	None.	None.....	25	890	36	696	32,040	2.17
VII.	July 9, 27.....	2	5-5-3-2-50.....	25	1,204	36	340	43,344	.78

THIRD COUNT OF INFESTED BERRIES MADE OCT. 9.

I.	June 19, July 8, 27.	3	5-5-3-50.....	25	997	36	2,326	35,892	6.45
II.	do.....	3	5-5-3-2-50.....	25	853	36	1,751	30,708	5.70
III.	do.....	3	5-6-1 qt.-2-50.....	25	842	36	1,503	30,312	4.95
IV.	do.....	3	5-6-1 qt.-50.....	25	835	36	1,083	30,060	3.60
V.	July 9, 27.....	2	5-6-1 qt.-2-50.....	25	744	36	1,681	26,784	6.27
VI.	Unsprayed.....	None.	None.....	25	890	36	3,549	32,040	11.07
VII.	July 9, 27.....	2	5-5-3-2-50.....	25	1,204	36	1,910	43,344	4.40

FOURTH COUNT OF INFESTED BERRIES MADE OCT. 23.

I.	June 19, July 8, 27.	3	5-5-3-50.....	25	997	36	4,655	27,544	16.90
II.	do.....	3	5-5-3-2-50.....	25	853	36	2,295	25,668	9.51
III.	do.....	3	5-6-1 qt.-2-50.....	25	842	36	2,648	24,552	10.78
IV.	do.....	3	5-6-1 qt.-50.....	25	835	36	2,295	24,232	9.74
V.	July 9, 27.....	2	5-6-1 qt.-2-50.....	25	744	36	2,288	23,562	9.71
VI.	Unsprayed.....	None.	None.....	25	890	36	3,149	23,000	13.69
VII.	July 9, 27.....	2	5-5-3-2-50.....	25	1,204	36	2,338	36,980	6.32

In making these counts it was observed that the infestation was very irregular throughout this block of vineyard. The first two or three rows on Plat I were heavily infested. The fruit on about 20 to 30 vines, on the east end of plats I, II, and III was also quite badly infested. Passing through Plats V, VI, and VII and toward the north side and the west end of the vineyard the infestation was much lighter, and on Plat VII and the extreme west end of Plats IV, V, VI, and VII the infestation was very light. This exceedingly variable condition of infestation has made the tabulation of results very difficult, and it has been quite impossible to bring out the relative value of the different poisons used and the value of the varying number of applications.

The results of the spraying operations for this season are quite indefinite and serve only to bring out the great irregularity in infestation, its progress throughout the season, and the difficulty in laying out a plat arrangement which will show accurately the effect of spray treatment against this pest. That some benefit did result from the spray application is indicated by the fact that in a comparison of infestation in Plats V, VI, and VII, where the infestation was lighter but more uniform than on the opposite side of the vineyard, there was throughout the season a greater infestation on the unsprayed plat than on the two adjacent sprayed plats. There was not sufficient difference in the weight of fruit from the different plats to indicate a commercial value resulting from the use of arsenate of lead as against arsenite of lime.

VINEYARD EXPERIMENTS WITH POISON SPRAYS IN 1908.

The spray work for 1908 was conducted in the same vineyard as in 1907. The plat arrangement, however, was changed. The number

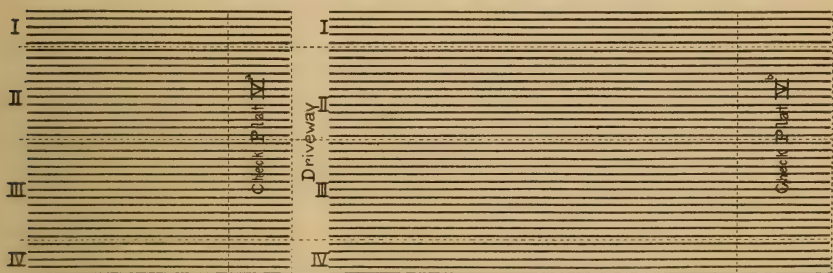


FIG. 21.—Plat arrangement of poison-spraying experiments against the grape-berry moth in the vineyard of Mr. W. S. Wheeler, North East, Pa., 1908 and 1909. (Original.)

of plats was reduced to four. Plat I consisted of 5 rows, Plat II of 12 rows, Plat III of 13 rows, and Plat IV of 5 rows. The position of the check or unsprayed plat was also changed. Checks were left in two places. In the west section 10 vines were left unsprayed on the east end of all the rows of the four plats; in the east section 15 vines were left unsprayed on the east end of all of the rows of the four plats. (See plan of plat arrangement, fig. 21.) The dotted line running across the plats near the east end of both sections indicates the location of the unsprayed check vines; these portions thus separated are numbered Plat Va and Plat Vb, respectively.

This rearrangement of plats was adopted in the hope that the infestation of the vines in these locations would more nearly represent that existing on the sprayed vines.

Arsenite of lime was eliminated from the spray formulas used, on account of slight injury to foliage. The spray formula on all four plats was the same. (See Table XXIV.)

TABLE XXIV.—*Spray formulas and dates of application against larvæ of the grape-berry moth. Vineyard of Mr. W. S. Wheeler, North East, Pa., 1908.*

Plat No.	Spray formula.	Number of spray applications.	Date of application.
I.....	Three pounds arsenate of lead and 2 pounds resin-fish-oil to 50 gallons of Bordeaux mixture.	2	June 4, 18.
II.....	do.....	3	June 4, 18; July 6.
III.....	do.....	2	June 19; July 6.
IV.....	do.....	1	June 19.
V a-b.	Unsprayed.		

The same spraying machine and the same nozzle arrangement were used as in 1907. The pressure maintained was from 100 to 125 pounds. About 100 gallons of spray were applied per acre. The first application was made June 4, just before the blossom buds opened. A double application was made at this date; that is, as soon as the plats had been sprayed once the same plats were gone over again. Only Plats I and II were sprayed at this date. On June 18, just after blossoming, when the berries were about the size of buckshot (Pl. VIII, fig. 1), all four of the plats were given a double spraying. About 100 gallons of spray were used at each application and a pressure of from 100 to 125 pounds was maintained. Plat II received a third application July 6. This also was a double application. In making these double applications the vines were covered very thoroughly by the spray.

As in the previous season the infestation proved to be widely variable, rendering it impossible to make a comparison of the value of the variation in the number of applications made to the different plats. The infestation was distributed in about the same general manner as in the previous year. Plat I, on the south side of the section, was the most heavily infested, the infestation gradually decreasing in the other plats toward the north side of the vineyard. Counts were made on 25 vines in each of the check plats and also in each of the sprayed plats to show the progress of infestation for the first and second broods. (See Table XXV, showing count of infested berries for 1908.)

TABLE XXV.—*Progress of infestation of fruit by larvæ of the grape-berry moth in experimental plats. Vineyard of Mr. W. S. Wheeler, North East, Pa., 1908.*

FIRST COUNT OF INFESTED BERRIES, MADE ON AUGUST 3, 4.

Plat No.	Date of spray application.	Spray formula.	Number of applications.	Number of vines examined.	Number of infested berries.
I.....	June 4, 18.	5-5-3-2-50	2	25	28
II.....	June 4, 18; July 6.	5-5-3-2-50	3	25	25
III.....	June 19; July 6.	5-5-3-2-50	2	25	21
IV.....	June 19.	5-5-3-2-50	1	25	31

TABLE XXV.—*Progress of infestation of fruit by larvæ of the grape-berry moth in experimental plats. Vineyard of Mr. W. S. Wheeler, North East, Pa., 1908—Continued.*

SECOND COUNT OF INFESTED BERRIES, MADE ON SEPTEMBER 24 TO 26.

Plat No.	Date of spray application.	Spray formula.	Number of applications.	Number of vines examined.	Number of infested berries.
I.....	June 4, 18.....	5-5-3-2-50.....	2	25	1,855
II.....	June 4, 18, 19; July 6.....	5-5-3-2-50.....	3	25	1,440
III.....	July 6.....	5-5-3-2-50.....	2	25	1,095
IV.....	June 19.....	5-5-3-2-50.....	1	25	960

FIRST COUNT OF INFESTED BERRIES MADE ON AUGUST 3, 4.

V a-b.....	Unsprayed.....	None.....	None.	25	387
Do.....	do.....	do.....	None.	25	198
Do.....	do.....	do.....	None.	25	153
Do.....	do.....	do.....	None.	25	67

SECOND COUNT OF INFESTED BERRIES, MADE ON SEPTEMBER 24 TO 26.

V a-b.....	Unsprayed.....	None.....	None.	25	4,495
Do.....	do.....	do.....	None.	25	2,899
Do.....	do.....	do.....	None.	25	2,466
Do.....	do.....	do.....	None.	25	1,588

When the fruit was harvested the crop from the sprayed and from the unsprayed plats was weighed. Table XXVI, in the columns under "Yield in pounds of fruit per acre," shows the difference in crop yield per acre on the sprayed and the unsprayed plats. The last column also shows the cash value of the increased yield per acre on the sprayed vines.

TABLE XXVI.—*Amount of fruit infested by the grape-berry moth on sprayed and unsprayed plats and cash value of spray benefit per acre. Vineyard of Mr. W. S. Wheeler, North East, Pa., 1908.*

Plat No.	Date of spray applications.	Number of applications.	Spray formula.	Average number of berries per cluster.	Total number of clusters.	Number of vines examined.
I.....	June 4, June 18.....	2	5-5-3-2-50.....	36	2,312	60
Va-Vb.....	Unsprayed.....			36	3,858	60
II.....	June 4, June 18, July 6.....	3	5-5-3-2-50.....	36	3,374	60
Va-Vb.....	Unsprayed.....			36	2,294	60
III.....	June 19, July 6.....	2	5-5-3-2-50.....	36	2,235	60
Va-Vb.....	Unsprayed.....			36	1,914	60
IV.....	June 19.....	1	5-5-3-2-50.....	36	1,751	60
Va-Vb.....	Unsprayed.....			36	1,796	60

Plat No.	Total number of berries.	Total number of wormy berries.	Per cent of wormy berries.	Date of examination.	Yield in pounds of fruit per acre.		Cash gain in yield of fruit on sprayed plats per acre (at 1½ cents per pound).
					Sprayed.	Unsprayed.	
I.....	83,232	4,452	5.3	Sept. 26	4,175	3,347	\$12.42
Va-Vb.....	102,888	11,989	11.6	do.....			
II.....	85,464	3,458	4.4	do.....			
Va-Vb.....	82,584	7,733	9.2	do.....	3,826	2,998	12.42
III.....	80,460	2,632	3.2	do.....	3,949	3,010	14.08
Va-Vb.....	68,904	6,577	9.8	do.....			
IV.....	63,136	2,309	3.6	do.....			
Va-Vb.....	64,656	4,136	6.3	do.....	3,186	2,455	10.96

VINEYARD EXPERIMENTS WITH POISON SPRAYS IN 1909.

The spray work for 1909 was conducted in the same vineyard as in 1907 and 1908. The plat arrangement was the same as in 1908. The unsprayed check vines were also in the same location as in 1908. (See fig. 21.) The same gasoline-engine spraying outfit was used as in the two previous seasons and the nozzle arrangement was also the same. A pressure of from 100 to 125 pounds was maintained and about 100 gallons of spray were applied per acre. The first application was made on Plats I and II June 8, just before the blossom buds opened. The second application was made June 28, after blossoming, when the berries were about the size of buckshot. At this date all four plats were sprayed. Plat II was given a double spraying on this date. The other plats received only one application at each date throughout the season. All four plats were sprayed July 9, when the berries were large enough to touch each other in the cluster. (See Table XXVII, showing spray formula and number of applications.)

TABLE XXVII.—*Spray formula and dates of applications against larvæ of the grape-berry moth. Vineyard of Mr. W. S. Wheeler, North East, Pa., 1909.*

Plat No.	Spray formula.	Number of spray applications.	Date of application.
I.....	Three pounds arsenate of lead to 50 gallons of Bordeaux mixture.	3	June 8, 28; July 9.
II.....	do.....	3	Do.
III.....	do.....	2	June 28; July 9.
IV.....	do.....	2	Do.
Va, Vb...	Unsprayed.....		

Counts of infested berries were made on 25 vines in each of the unsprayed check plats and also in each of the sprayed plats. (See Table XXVIII, showing progress of infestation for season of 1909.)

TABLE XXVIII.—*Progress of infestation of fruit by larvæ of the grape-berry moth in experimental plats. Vineyard of Mr. W. S. Wheeler, North East, Pa., 1909.*

FIRST COUNT OF INFESTED BERRIES, MADE ON JULY 25.

Plat No.	Date of spray application.	Spray formula.	Number of applications.	Number of vines examined.	Number of infested berries.
I.....	June 8, 28, July 9.....	5-5-3-50.....	3	25	23
II.....	do.....	5-5-3-50.....	3	25	14
III.....	June 28, July 9.....	5-5-3-50.....	2	25	17
IV.....	do.....	5-5-3-50.....	2	25	12

SECOND COUNT OF INFESTED BERRIES, MADE ON SEPTEMBER 21 TO 24.

I.....	June 8, 28, July 9.....	5-5-3-50.....	3	25	750
II.....	do.....	5-5-3-50.....	3	25	396
III.....	June 28, July 9.....	5-5-3-50.....	2	25	550
IV.....	do.....	5-5-3-50.....	2	25	390

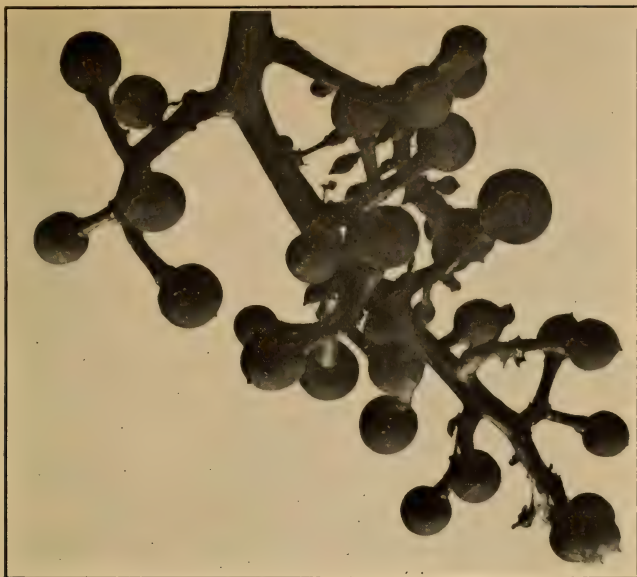


FIG. 1.—SHOWING SIZE OF GRAPE BERRIES AT SECOND SPRAY APPLICATION ABOUT THE TIME MANY OF THE FIRST-BROOD EGGS OF THE GRAPE-BERRY MOTH ARE DEPOSITED ON THEM. (ORIGINAL.)



FIG. 2.—TRAILER METHOD OF VINEYARD SPRAYING IN ORDER TO APPLY THE SPRAY TO THE UNDERSIDE OF THE FOLIAGE OR TO THE GRAPE CLUSTERS WHERE THE FOLIAGE IS DENSE. (ORIGINAL.)

TABLE XXVIII.—*Progress of infestation of fruit by larvæ of the grape-berry moth in experimental plats. Vineyard of Mr. W. S. Wheeler, North East, Pa., 1909—(Contd.)*

FIRST COUNT OF INFESTED BERRIES, MADE ON JULY 25.

Plat No.	Date of spray application.	Spray formula.	Number of applications.	Number of vines examined.	Number of infested berries.
Va, Vb.....	Unsprayed.....	None.....	None.	25	34
Do.....	do.....	do.....	None.	25	28
Do.....	do.....	do.....	None.	25	21
Do.....	do.....	do.....	None.	25	19

SECOND COUNT OF INFESTED BERRIES, MADE ON SEPTEMBER 21 TO 24.

Va, Vb.....	Unsprayed.....	None.....	None.	25	1,574
Do.....	do.....	do.....	None.	25	890
Do.....	do.....	do.....	None.	25	468
Do.....	do.....	do.....	None.	25	1,168

The counts were made July 25 and September 21 to 24. The infestation this season, as in 1907 and 1908, was heavier on the south side of Plat I and on the east end of the east section and became lighter toward the north side and west end of the vineyard, a condition which existed throughout the three seasons.

When the crop was harvested it was found that there was practically no difference in weight of fruit per acre on the sprayed and the unsprayed vines. Taking the vineyard as a whole the infestation was very much lighter than in either of the preceding seasons. (See Table XXIX, showing percentage of infected berries on fruit from 25 vines in each of the sprayed and the unsprayed plats.)

TABLE XIX.—*Percentage of grape berries infested by larvæ of the grape-berry moth on 25 vines in sprayed and unsprayed plats. Vineyard of Mr. W. S. Wheeler, North East, Pa., 1909.*

SPRAYED.

Plat No.	Dates sprayed.	Number of times sprayed	Formula.	Number of vines examined.	Total number of clusters.	Average number of berries per cluster.	Number of infested berries.	Total number of berries.	Percentage of infested berries.	Date clusters were examined.
1909.										
I...	June 8, 28, July 9.	3	5-5-3-50.....	25	1,512	38	750	57,456	1.30	Sept. 21-24
II.	do.....	3	5-5-3-50.....	25	1,242	38	396	47,196	.84	Do.
III.	June 28, July 9.	2	5-5-3-50.....	25	1,203	38	554	49,514	1.12	Do.
IV.	do.....	2	5-5-3-50.....	25	1,288	38	390	48,944	.79	Do.

UNSPRAYED.

Va	} Unsprayed....	None..	None.....	25	1,102	38	1,574	42,256	3.72	Sept. 21-24
Vb		do..	do.....	25	994	38	890	37,772	2.36	Do.
Va		do..	do.....	25	747	38	468	26,562	1.77	Do.
Vb		do..	do.....	25	1,182	38	1,168	44,916	2.60	Do.
Va		do..	do.....	25	1,182	38	1,168	44,916	2.60	Do.

In considering the results of the spray experiments presented in the foregoing paragraphs the casual reader might infer that the benefit derived does not offset the cost of the operation. Charging the total expense to this particular insect, this would probably hold true for the seasons of 1907 and 1909. The treatment for 1908 shows a cash increase in crop yield, however, which more than offsets the cost of spray treatment for that season. It should be remembered, too, that these spray applications serve to protect the grapevines against the grape rootworm and the fruit and foliage against fungous diseases. For both of these infestations it is desirable to make the spray applications at about the same dates that the applications are recommended to be made for the control of the larvæ of the grape-berry moth. Hence the additional expense involved in the increased amount of spray material used in making applications thorough enough to be effective in decreasing the infestation of the grape berries by this insect is not very great.

The cost of spray material and labor for each application at the rate of about 100 gallons per acre was approximately \$2 per acre for each application. Furthermore, there is no doubt that the poison-spray application covering the three seasons greatly reduced the infestation throughout the vineyard, for at the end of the third season's treatment the infestation was manifestly much less than when the experiment was commenced.

RECOMMENDATIONS FOR CONTROL.

At the present state of our knowledge of the habits of this pest and of the methods that have been suggested and employed for its control it is impossible to recommend any one method which of itself has given results that are as satisfactory as could be wished. The life-history studies made during this investigation, which have been discussed under that head, indicate that we have been in error in assuming that there are three broods of this insect in the Lake Erie Valley. According to Prof. Slingerland the first brood develops in the blossom clusters and the recently set berries. The summer or second brood develops on the green grapes during July and early August and a partial third brood occurs in autumn.

On the strength of these statements much emphasis has been placed upon the importance and probable efficiency of a poison spray applied to the vines just previous to blossoming to destroy the larvæ of the first brood which feed upon the blossom cluster. The life-history studies made during this investigation, however, indicate that only about 25 per cent of the spring moths emerge previous and up to the time that the blossom buds break into bloom. Hence no matter how effective this first poison application may be in the destruction of the larvæ actually feeding upon the blossom

clusters it is ineffective against the larger portion of the first brood of larvæ, since at this time only a small portion of them have hatched. On the other hand, it is of great importance to destroy as many as possible of these early appearing larvæ, since the adults into which they develop deposit eggs for the second brood. With our present knowledge that the majority of the larvæ of this first brood do not appear until after the berries have set, this first poison application previous to blossoming can no longer be emphasized as the most important spray treatment, to the extent of regarding later applications as of little value or of withholding them entirely. In fact, with the knowledge that the majority of the larvæ hatch after the blooming period during the first two weeks in July, additional attention should be given to making the spray application very thorough during this period. It is quite probable that a single poison-spray application just before the blossom buds open, followed by a heavy double application about the first week in July just after the berries have set and at a time when the maximum number of larvæ are hatching, will doubtless give the most satisfactory results to be secured from a spray treatment. A study of the experimental results secured in the season of 1908, when this heavy double-application method was followed, indicates that better net results were secured from these double-spray applications than in the seasons of 1907 and 1909, when the plan of making a single application at each date of spraying was followed.

Where these heavy double-spray applications are resorted to it is suggested that a Bordeaux formula consisting of 3 pounds of lime and 3 pounds of copper sulphate to 50 gallons of water be employed instead of 5 pounds of lime and 5 pounds of copper sulphate as is sometimes recommended. The reason for suggesting this weakening of the Bordeaux formula is that injury to the foliage of the grapevine has been observed to result from very heavy and frequent applications of the stronger formula.

In making spray applications against this insect it is very desirable that a high pressure be maintained in order to force the poison spray into the cluster so that all of the berries may be covered. (See Pl. VIII, fig. 1, showing size of grape berries at date of second spray application, at about the time many of the first-brood eggs of the grape-berry moth are deposited.) If at the second spraying this can not be done with a stationary nozzle arrangement on account of the dense foliage, the trailer method of application used against the grape leafhopper may be employed. (See Pl. VIII, fig. 2.)

When the grape leafhopper is at all numerous in vineyards where spraying treatment for the grape-berry moth is necessary, a combination spray may be used against both insects during the early part of July, using the "trailer" method of application.

Commercial tobacco extracts (blackleaf tobacco extract, containing $2\frac{7}{10}$ per cent nicotine sulphate) applied at a dilution of 1 to 150 gallons of water, or a still more highly concentrated form ('blackleaf 40,' containing 40 per cent nicotine sulphate) applied at a dilution of 1 to 1,500 gallons of water, may be used with arsenate of lead. The tobacco extract is used on the leaf as a contact remedy against the nymphs of the grape leafhopper and the arsenate of lead on the fruit against the larvæ of the grape-berry moth. Paris green and arsenite of lime should not be mixed with the tobacco extracts as a substitute for arsenate of lead, for serious foliage injury results from these combinations.

The combination-spray application against these two insects should be made by the "trailer" method, as shown in Plate VIII, figure 2. The nymphs of the grape leafhopper suck the juice from the underside of the grape leaves and are killed by the tobacco extracts coming in contact with their bodies; hence, in making this application to the underside of the grape foliage most of the grape clusters are drenched by the spray. By the addition of arsenate of lead this application may also act as a treatment against the larvæ of the grape-berry moth.

Since no serious infections of black rot have occurred in the vineyards of the Lake Erie Valley during the past few seasons, the stronger fungicide formula does not appear to be necessary. Hence the combination spray formula recommended against this pest is as follows:

Lime.....	} Bordeaux formula.....	pounds..	3
Copper sulphate.....		do.....	3
Water.....		gallons...	50
Arsenate of lead (insecticide).....		pounds..	3

Since the effectiveness of an arsenical spray treatment depends upon the presence of the poison upon the blossom clusters and upon the berries when the larvæ hatch from the eggs and commence to feed upon the blossom buds and berries, and since this period varies more or less each season, it is impossible to give definite dates at which the applications should be made. Hence the development of the blossom clusters and the formation of the berries will doubtless indicate more accurately the hatching period of the larvæ. The following spray schedule is based on the blossoming period of the grape and the development of the berries:

First application just previous to the blossoming period (see fig. 20) to poison the larvæ which feed in the blossom cluster, from about June 8 to 14.

The second application should be made immediately after blossoming, at which time the larvæ commence to feed upon the newly set berries, and the application should be doubled over those portions

of the vineyard where the infestation has been heavy during previous seasons. The time of this second application is approximately from June 20 to 30.

The third application should be made when the berries are about the size of buckshot (see Pl. VIII, fig. 1). If the foliage is dense, the "trailer" method of application should be employed, and if the grape leafhopper is at all numerous the tobacco extract should be added to control the latter insect. The time of this third application is approximately from July 5 to 15.

The poison-spray treatments recommended against the grape root-worm are also covered by the second and third applications against the grape-berry moth.

It should be distinctly understood by the vineyardist that the arsenate of lead is the active killing agent employed against the larvæ of the grape-berry moth and that it is applied with the Bordeaux mixture, which is a fungicide, in order to avoid the duplication of applications.

Where a considerable number of infested grape berries are observed on vineyard areas that received a poison-spray application before the grape blossoms opened, and a heavy double application after the berries had formed, it may be necessary to hand pick the infested berries during the latter part of July before many of the larvæ of the first brood have fully developed. By removing these larvæ from the vineyard and destroying them by immersing the infested berries in boiling water, the amount of infestation by the second brood of larvæ may be greatly reduced. ●

Should only limited areas of the vineyard prove to be seriously infested at the approach of the picking season, as frequently occurs, it is suggested that the vineyardist remove the fruit from these vines as early as possible, for in doing so he may be able to remove a good many of the larvæ from the vineyard which would otherwise remain there to reinfest the crop of the succeeding season.

In addition to the control methods suggested against the larvæ, special effort should be made to destroy the pupæ which pass the winter in the fallen leaves, on the ground beneath the trellis. (See fig. 22.) As previously mentioned, observations made during this investigation indicate that the majority of the pupæ over-winter in cocoons made upon leaves which have fallen prematurely to the ground beneath the trellis. These leaves are frequently stuck to the soil and are in a state of semidecay before the rest of the foliage has fallen from the vines. Hence there is little likelihood that many of these leaves bearing the cocoons will be blown out of the vineyard. For this reason it is quite probable that if 2 or 3 inches of soil are thrown under the trellis in late fall or early spring many of the pupæ may be destroyed by this operation. It is not known positively that

plowing under the pupa-infested leaves in this manner will destroy the insect in this stage, but it is highly probable that many fatalities will result from the method. It is believed that greater success will result from an endeavor to destroy the pupæ which are in cocoons upon leaves that remain in the vineyard throughout the winter than in the destruction of leaves outside of the vineyard which are blown into fence rows, ditches, and adjacent rough lands. No moths of this insect have been reared from grape leaves gathered from these latter locations, although several attempts have been made to secure specimens from them.

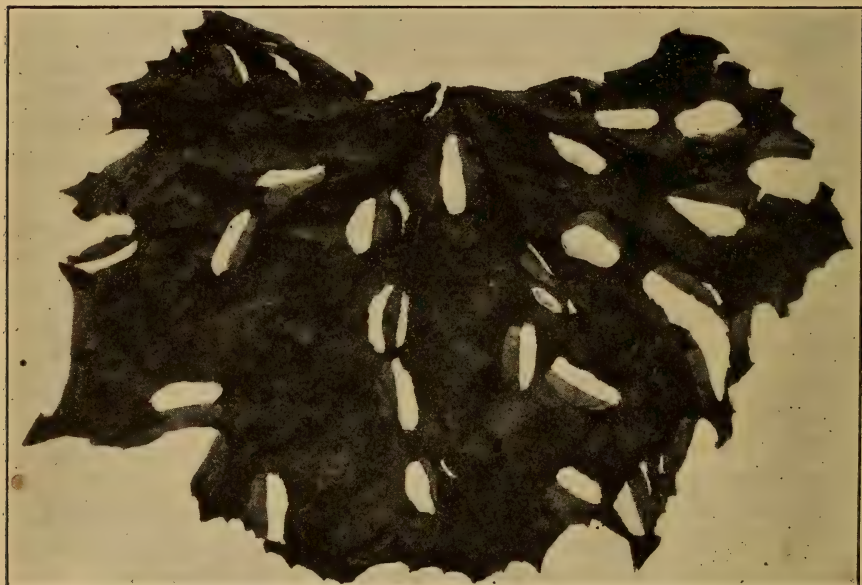


FIG. 22.—Overwintering cocoons of the grape-berry moth upon leaf on ground, beneath a badly infested grapevine. (Original.)

CONCLUSION.

Wherever vineyards have become badly infested by the grape-berry moth serious injury to the crop has resulted and the owners of the infested vineyards have found it a very difficult pest to eradicate. Many vineyardists who have tried to control the pest with a poison spray have not met with as complete success as they would wish. Many such instances of complete or partial failure have been observed. In nearly all of these cases, however, investigation has shown that this lack of success, in all probability, was largely due, either to inferior spraying equipment which failed to deliver the spray in sufficient quantity and force to thoroughly cover the clusters, or to the fact that the applications were not made at a time when the majority of the larvæ were about to hatch. Frequently both of these condi-

tions have occurred simultaneously, and as a result, failure has been complete. For this reason the spray method of control is looked upon with disfavor by many who have carried on the work under these conditions.

In vineyards where infestation is at all serious vineyardists are urged to give the spray method a thorough trial for a period of several consecutive seasons. If the infestation is confined to a limited area, as is frequently the case, the owner can well afford to make additional applications over this area to prevent it from increasing and spreading farther into the vineyard and possibly, at some future time, causing the loss of a large percentage of the crop over the entire area.

A lack of knowledge of the extent of the infestation of his vineyard by this pest during the early stages of the first brood is perhaps one of the chief causes for lack of successful control by the owner. It is hoped that with the aid of the data contained in this paper under "Seasonal history" the vineyardist will be better able to determine the periods when the maximum number of larvæ leave the eggs to enter the berries, and with the additional aid of more efficient high-pressure power-spraying machinery now available for this work it is believed that the poison-spray method of control will prove to be the most effective and practical means of controlling this pest.

Combination spray mixtures, whereby other insect pests of the grapevine can be controlled by the same applications made against the grape-berry moth, have been suggested under the head of recommendations for control and are worthy of trial in the endeavor to reduce the cost of controlling several of the pests that infest the fruit and foliage of the grape in the vineyards throughout the Lake Erie Valley. This phase of control work will receive some attention in connection with further studies to be made of grape pests, by the Bureau of Entomology, in this region.

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1909. EHRHORN, E. M.—New pests we should guard against. <3d Bien. Rept. Comm. Hort. [Cal.] (1907-08), p. 59.

As yet *Polychrosis viteana* does not occur in California.

1910. SMITH, J. B.—Ann. Rept. N. J. State Mus. (1909), with Rept. of N. J. Insects, p. 538.

Sometimes *Polychrosis vitana* causes trouble locally throughout New York. There are three broods. Spraying with arsenate of lead is recommended to kill off the first brood.

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U. S. DEPARTMENT OF AGRICULTURE,
BUREAU OF ENTOMOLOGY—BULLETIN No. 116, Part III.

L. O. HOWARD, Entomologist and Chief of Bureau.

PAPERS ON DECIDUOUS FRUIT INSECTS
AND INSECTICIDES.

THE CHERRY FRUIT SAWFLY.

BY

S. W. FOSTER,
Entomological Assistant.

ISSUED JANUARY 31, 1913.



WASHINGTON:
GOVERNMENT PRINTING OFFICE.

1913.

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DECIDUOUS FRUIT INSECT INVESTIGATIONS.

A. L. QUAINANCE, *in charge.*

FRED JOHNSON, S. W. FOSTER,¹ F. E. BROOKS, A. G. HAMMAR, E. W. SCOTT, R. L. NOUGARET, R. A. CUSHMAN, L. L. SCOTT, J. B. GILL, A. C. BAKER, W. M. DAVIDSON, E. B. BLAKESLEE, W. B. WOOD, E. H. SIEGLER, F. L. SIMANTON, *entomological assistants.*

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¹ Resigned.

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PAPERS ON DECIDUOUS FRUIT INSECTS AND INSECTICIDES.

THE CHERRY FRUIT SAWFLY.

(Hoplocampa cookei [Clarke]).

By S. W. FOSTER,

Entomological Assistant.

INTRODUCTION.

The cherry fruit sawfly is an insect comparatively little known to science. It was first described by Prof. W. T. Clarke in the Canadian Entomologist, volume 38, No. 11, page 353, under the name *Dolerus cookei*. In 1910 specimens of this species were brought to the attention of Mr. S. A. Rohwer, of the Bureau of Entomology, who referred it to the genus *Hoplocampa*. As he was unfamiliar with the type of *cookei*, he considered that it represented an undescribed species, for this latter was destroyed in the insect collections by the San Francisco fire. Mr. Rohwer, however, as a result of the examination of abundant material, has come to the conclusion that his and Clarke's species are the same insect, which should now be known under the name of *Hoplocampa cookei* (Clarke). Mr. Rohwer's description of the species as *Hoplocampa californica* is given herewith, as taken from Technical Series No. 20, Part IV, of this bureau, page 143:

Female.—Length 3.5 mm. Clypeus broadly, shallowly, angulately emarginate, lobes broad, obtusely triangular; supraclypeal area convex, finely granular; antennal furrows wanting, antennal foveæ small; middle fovea elongate, shallow, not well defined; ocellar depression small, distinct, not sharply defined; postocellar area well defined on all sides; head and mesoscutum with small, separate, well-defined punctures; antennæ rather slender, third and fourth joints equal; sheath slightly concave above, slender, convex below from apex; cerci short, stout; stigma broadest near base, strongly tapering to apex; transverse radius strongly oblique, in apical third cell; third cubital cell longer than first and second combined. Black; clypeus, labrum, mandibles (except piceous apices), orbits, occiput (except postocellar), tegulæ, anterior legs (except coxæ), intermediate femora, and part of posterior femora reddish yellow; posterior femora in part, most of four hind tibiæ, and tarsi black or brownish; wings hyaline, iridescent; venation pale brown, stigma in part pallid.

Paratopotypes show that the four hind legs may be mostly black, the posterior orbits pale and the pale spots of the occiput reduced in size.

Male.—Length 3 mm. Clypeus more obtusely emarginate than in female; third joint shorter than fourth; stigma not strongly tapering; hypopygidium narrowly rounded at apex. Black; antennæ, head (except interocellar area), margin of mesoprescutum, latr. pectus, legs, and venter reddish yellow; wings as in female.

Type locality.—Suisun, Cal., March 10, 1910 (R. W. Braucher); eight females and one male.

Type.—Catalogue No. 13471, U. S. National Museum.

On April 20, 1909, while inspecting the cherry orchard of Mr. Charles Barnes, Suisun, Cal., for the extent of injury caused by the pear thrips, the writer found several cherries infested with small white hymenopterous larvæ. The full-grown larvæ were about five-sixteenths of an inch long and apparently did most of the feeding inside of the kernel, or in the flesh immediately adjoining the kernel. Although the cherry crop was light the injury was quite general, and further search on April 25 showed the little larvæ in greater or less numbers in most of the cherry orchards of the Suisun Valley. A large series of counts made of the fruit in Mr. Barnes's orchard showed approximately 80 per cent of the fruit to have been injured by these larvæ.

At this latter date, April 25, most of the larvæ were full grown. Some had evidently finished feeding and had left the fruit. However, careful search in the ground under the trees failed to show the presence of any larvæ or pupæ. A large quantity of infested fruit (See Pl. IX, figs. 1, 2) was taken to the laboratory for further study and life-history observations.

SEASONAL HISTORY AND HABITS.

All of the larvæ in the rearing cages had left the fruit and had gone into the soil in the bottom of the cages by May 5, 1909. None of them pupated among the sticks and trash which had been placed in the cages on top of the soil. The cages were sunk in the ground to approach as nearly as possible the normal out-of-doors conditions. Unfortunately all of these larvæ were killed by drainage water from a near-by sink seeping into the cage during the absence of the writer.

In June, 1912, the writer received from Mr. P. J. O'Gara, Medford, Oreg., a consignment of cherries showing the characteristic injury caused by this species. Mr. O'Gara stated that he had observed the larvæ in a few orchards in one locality in Jackson County, Oreg., and that this insect also attacked prunes.

So far as the writer has learned this is the only occurrence of the cherry fruit sawfly outside of the State of California.

THE ADULT.

Close watch was kept in the spring of 1910 for the first appearance of adults in the field. Mr. R. W. Braucher, who was detailed to look after the demonstration spraying for pear thrips in that locality

for the Bureau of Entomology, kept a close watch for the first appearance of the adults of this species. On March 10, 1910, he found three female sawflies (see fig. 23, *d*) in cages planted under trees in the orchard and used for the emergence records of the pear thrips. Four more adults were caught in the cages on March 12, and two dead ones were found outside of the cages. These had evidently been killed by the spraying for thrips the previous morning. The first males were found March 16 and after this date both sexes were quite numerous for some two weeks or more. The Black Tartarian cherries were just beginning to bloom at this time.

The writer spent considerable time in the Suisun section at this period, making a further study of the life history and habits of the

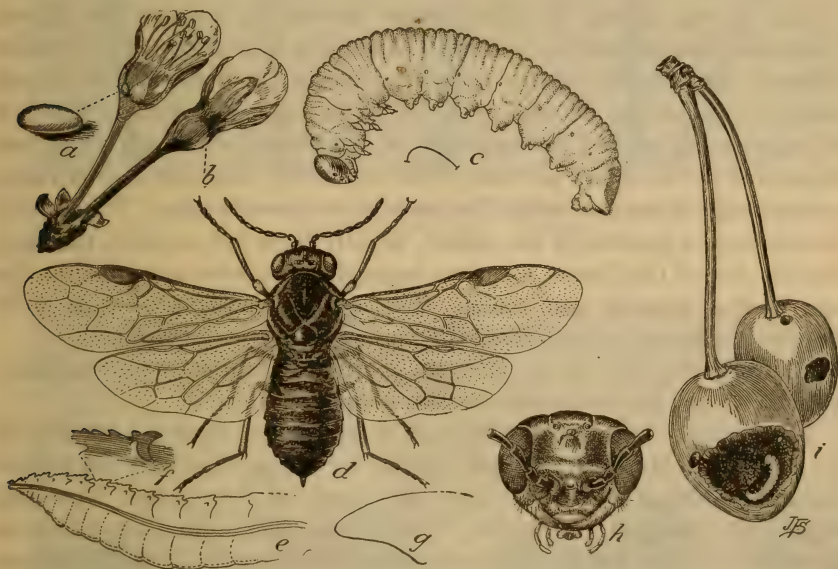


FIG. 23.—Stages and work of the cherry fruit sawfly (*Hoplocampa cooki*): *a*, Egg; *b*, position of egg in cherry blossom; *c*, larva; *d*, adult sawfly; *e*, saw of ovipositor; *f*, serrations on ovipositor; *g*, sheath of saw; *h*, head of adult sawfly; *i*, infested cherries. (Original.)

insect. By March 20 adults of both sexes were plentiful, but the females far outnumbered the males. As many as 40 individuals were observed in one tree, two-thirds to three-fourths of which were females. The adults were very sluggish in the early mornings and could be picked up with little or no difficulty. Toward noon, as the atmosphere grew warmer, they became more active, but even then many individuals could be caught in the trees. The adults may be found resting on the leaves, leaf stems, blossoms, both outside and inside, and on the twigs. A few were observed feeding on the nectar of the more advanced flowers. In confinement the adults fed quite freely upon sirup and water.

Egg laying had begun only sparingly on March 21, but by the afternoon of March 23 many eggs could be found. A thorough search in three different orchards failed to show any larvæ. Oviposition was at its height about March 23 to 30, and was practically over by April 5, the adults having mostly disappeared by this time. The females seem to die off in advance of the males, showing about the same comparative difference as was the case at the beginning of the emergence. On April 3 and 4 as high as eight males to one female were noted. On April 6, two orchards were closely examined, and while many males were in evidence not one female could be found.

THE EGG.

Egg laying began in 1910 about March 16, just as the Black Tartarian cherries were beginning to open first blossoms. The females oviposit quite freely in the orchards, always on blossoms just about ready to spread the petals. (See Pl. X, fig. 1.) The greater number of eggs are deposited in the sepals of the flower, although some are deposited in the upper portion of the calyx cup, but only in rare cases are any eggs deposited below the middle of the calyx cup. The female inserts her ovipositor in the tissue, usually from the outside, making, for the size of the insect, a rather large, deep incision and placing the egg in the opening just made. The egg is usually placed at such depth that it can be seen from the opposite side of the sepal.

The egg (fig. 23, *a*) is 0.5 mm. long by 0.3 mm. wide, whitish, slightly shiny, and somewhat kidney-shaped.

Incubation.—Of a total of 35 eggs deposited between 8 a. m. March 21 and 8 a. m. March 22, 27 had hatched by 8 a. m. March 25, the others hatching during the day. Another batch of four eggs, deposited March 25, hatched March 30. There were three other observations in which the eggs hatched in five days after oviposition. Mr. Braucher reports another instance of eggs that were deposited on March 28 hatching in the afternoon of March 31. The summary of these records together with many field observations shows the length of time required for incubation to vary from three to six days, averaging from four to five days. This time is influenced by temperature conditions, as eggs kept indoors required from 18 to 36 hours longer than eggs kept outside. The time of hatching coincides very closely with the falling of the petals from the blossoms of the variety attacked. Usually the eggs are deposited at or just prior to the opening of the petals and hatch with the falling of the petals. One very interesting observation was that the adults invariably deposit their eggs at this stage of blossom development regardless of the variety. In one



FIG. 1.—CHERRIES INJURED BY THE CHERRY FRUIT SAWFLY (*HOPLOCAMPA COOKEI*).
TWICE NATURAL SIZE. (ORIGINAL.)



FIG. 2.—ENTRANCE AND EXIT HOLES OF THE CHERRY FRUIT SAWFLY. NATURAL SIZE
OR TWICE NATURAL SIZE. (ORIGINAL.)

WORK OF CHERRY FRUIT SAWFLY LARVÆ IN IMMATURE CHERRIES.



FIG. 1.—CHERRY BLOSSOM CLUSTERS AT STAGE OF DEVELOPMENT WHEN MOST OF THE EGGS OF THE CHERRY FRUIT SAWFLY ARE BEING DEPOSITED. ABOUT TWICE NATURAL SIZE. (ORIGINAL.)



FIG. 2.—LARVÆ AND COCOONS OF THE CHERRY FRUIT SAWFLY. ABOUT FOUR TIMES NATURAL SIZE. (ORIGINAL.)

orchard under observation there were early and late blooming cherries in alternating rows. Eggs of this insect were numerous and a few larvæ present before the adults apparently noticed the later-blooming varieties. Afterwards, when the petals of the Royal Anne cherry were beginning to open, eggs were just being deposited in numbers in this variety while the Black Tartarians immediately adjoining these trees had shed the petals and the larvæ had mostly hatched and only very rarely could an egg be found. The time required for incubation of the egg is practically the same in all varieties of fruits. Ordinarily only one egg is deposited in a single flower. Occasionally, however, two and very rarely three eggs were found in the sepals and calyx of one flower.

THE LARVA.

Upon hatching the young larva may feed for a short time in the tissue immediately surrounding the egg cavity, or on the inner surface of the calyx cup, but it soon finds its way to the bottom of the calyx cup and eats directly into the newly formed cherry. The larva at this time almost always enters the fruit through the base immediately adjoining or very near the stem. Going directly to the center of the cherry, the larva eats away the small kernel. The cherry thus injured soon withers. In two to four days after entrance the larva makes its first molt and leaves this cherry in search of other and fresh food. When attacking the second cherry the larva may enter the fruit through almost any place on the surface but invariably goes directly to the seed, and if this has not hardened eats out the kernel, as was done with the first fruit, seeming to prefer this to the meat of the cherry. The second cherry, being larger when attacked, usually withstands the effects of feeding longer and the larva may remain inside for some six to ten days or even longer. The growth of the cherry is checked and it frequently hangs on the tree retaining a rather pale green color for some days after growth ceases and the fruit has shriveled. When the kernel in this second cherry has been destroyed the larva usually goes to a third cherry and if the pit has not hardened eats it out as before. However, when the pits become too hard the larva feeds on the meat of the cherry near the pit until it attains full growth in much the same manner as does the plum curculio in peaches. In Plate IX are shown photographs of the injured fruit and the entrance and exit holes of the larvæ.

Each larva usually destroys three cherries, although some go to the fourth, while a very few complete their growth in the second cherry. The time required for the larvæ to attain their full growth averages from 22 to 26 days. In Table I the record is given for 34 individuals.

TABLE I.—Length of larval stage of the cherry fruit sawfly, Swisun, Cal., 1910.

Date.	Observation.
1910.	
Mar. 25...	34 larvæ hatched in cherry blossoms in cage.
Mar. 27...	Supply of fresh food given (branches of young fruit from cherry tree).
Mar. 30...	24 larvæ had entered second cherry.
Apr. 1...	6 more larvæ had entered second cherry.
Apr. 6...	Fresh food put into cage.
Apr. 8...	16 larvæ found in third cherry; 6 larvæ still in second cherry.
Apr. 12...	Fresh food put into cage.
Apr. 16...	3 full-grown larvæ left fruit.
Apr. 17...	2 full-grown larvæ left fruit.
Apr. 18...	5 full-grown larvæ left fruit.
Apr. 19...	Do.
Apr. 20...	3 full-grown larvæ left fruit and 5 full-grown larvæ found in trash at bottom of cage. All the larvæ had left fruit at this date.

When full grown (see fig. 23, c) the larva leaves the fruit and works its way into the ground, where it constructs a small parchment-like cocoon. The cocoon will be found from 3 to 7 inches below the



FIG. 24.—*Microbracon* sp., a hymenopterous parasite of the cherry fruit sawfly (*Hoplocampa cooki*). (Original.)

surface, the depth varying somewhat with the texture of the soil. It is elliptical or oval in shape and from one-fourth to three-eighths of an inch long. Inside the cocoon is smooth, dark brown in color, of a papery texture, and somewhat brittle, especially in dry soil, so that it is easily broken.

The outer surface of the cocoon is covered with fine particles of soil, giving it the appearance of a small clod of dirt. In Plate X, figure 2, are shown full-grown larvæ and cocoons, some of the latter being torn partly open.

The larva remains as such in the cocoon until the following winter. Some time after the winter rains begin it transforms to pupa and emerges the following March as adult.

The pupa has not been observed. There is only one brood each year.

NATURAL ENEMIES.

Two parasites, an ichneumon and a microbracon (see fig. 24), were obtained from the material collected by Mr. Braucher.

Several large collections of infested fruit were brought to the laboratory for possible parasites, but none was obtained from this

material. It is possible that this species is rather heavily parasitized at times. The insect has been known in the Suisun Valley since 1905, but caused comparatively little injury from that time until the serious outbreak of 1909. As no spraying had been done in the infested orchards that would be of any value as a control to this particular species it would seem that the parasites, together with more thorough cultivation, have served to keep it fairly well in check. The insect was less numerous in 1910 than in 1909 and the same was true of the years 1911 and 1912.

EXPERIMENTS IN CONTROL.

Experiments in spraying with arsenate of lead were made in 1910, but in this instance the poison did not prove to be altogether effective. Some larvæ were killed, but not enough to warrant the recommendation of this as a satisfactory treatment in case of a serious outbreak of the insect. Further work along this line is desirable. Mr. O'Gara, in a letter, reports satisfactory results from the use of arsenate of lead in the Rogue River Valley of Oregon.

Many adults were killed in the early mornings while spraying with 3 per cent distillate-oil emulsion to which sulphate of nicotine had been added at the rate of 1 part to 2,000 parts of water. This method would most likely be a very effective means of control if all the spraying could be done in the early morning. At this time the adults are very sluggish and can be easily wet with the spray.

Perhaps a more likely means of holding this sawfly in check is by careful cultivation. The most serious hindrance to this plan of treatment in cherry orchards is that the roots of the cherry tree close to the trunk are near the surface, and some larvæ go below the top of these roots. However, it is highly advisable to cultivate the land thoroughly two or three times just prior to the first picking of the Black Tartarian cherries, as most of the larvæ are leaving the trees at this time and numbers of them would probably be killed.

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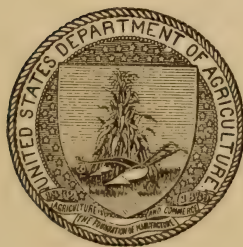
PAPERS ON DECIDUOUS FRUIT INSECTS
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LIME-SULPHUR AS A STOMACH POISON
FOR INSECTS.

BY

E. W. SCOTT AND E. H. SIEGLER,
Entomological Assistants, Deciduous Fruit Insect Investigations.

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PAPERS ON DECIDUOUS FRUIT INSECTS AND INSECTICIDES.

LIME-SULPHUR AS A STOMACH POISON FOR INSECTS.

By E. W. SCOTT and E. H. SIEGLER,

Entomological Assistants, Deciduous Fruit Insect Investigations.

INTRODUCTION.

During the season of 1912 the branch of Deciduous Fruit Insect Investigations of the Bureau of Entomology, at its laboratory at Benton Harbor, Mich., conducted a series of feeding experiments to test the killing effect of various poisons on different species of insects. In the course of the work it was soon noted that lime-sulphur, when combined with certain slow-acting arsenicals and doubtful stomach poisons, increased their insecticidal value. This clue was followed up and a considerable series of feeding tests was made during the succeeding months. These experiments indicate that lime-sulphur spray alone, at the strength used in spraying orchards in foliage, has a decided insecticidal action as a stomach poison. It will be remembered that lime-sulphur as an insecticide has been heretofore considered solely as a contact spray. In this paper are given the results obtained from the use of lime-sulphur and arsenate of lead, separately and in combination.

CONDITIONS OF THE EXPERIMENTS.

The fall webworm (*Hyphantria cunea* Drury) (see Plate XI) was used for most of the feeding tests, since this insect was readily obtained in large numbers. Furthermore, it was easily handled, was rather resistant to poisons, and on the whole proved an ideal species for the work at hand. The stock supply was collected in the field and brought to the laboratory where the tests were made. Only the very young larvæ, usually three or four days old, were used, and whenever possible those from the same nest were used for the same experiment. When two or more nests of larvæ were necessary for use in a given experiment, care was taken to use those of as nearly the same age as possible.

The wild black cherry (*Prunus serotina*) was found to be a favorite food plant of the fall webworm in Michigan. In addition, the foliage stood up well when the branches were placed in water, and, further,

was rather resistant against the burning effect of the spray materials. Twigs bearing from 20 to 30 leaves were employed.

The spray was applied to the foliage by means of a large atomizer of the type in which quart jars are used as a container for the liquid. The twigs were sprayed until the leaves began to drip, approaching as nearly as possible the conditions of field spraying operations. Each sprayed twig was then placed in a jelly glass of water, the stem extending through a hole punched in the tin cover. (See Plate XI, figs. 1, 2.)

After the spray had thoroughly dried, allowing from 6 to 12 hours, 20 insects were placed on the leaves of each twig. A large paper bag was then placed over the twig and held to the glass by means of a rubber band. (See Plate XI, fig. 1, at right.)

Observations were usually made every other day; in some cases every day. At each examination the bag was removed and the dead larvæ taken out and counted. When all the insects were dead, or had pupated, as the case might be, the amount of foliage consumed was measured in square inches. A sheet of celluloid cross-sectioned to one one-hundredth of a square inch was utilized for this purpose. These measurements were easily taken, where effective poisons were used, as the young larvæ died before very much foliage had been consumed. The younger larvæ ate only one surface of the leaf, but as they increased in size the leaves were often skeletonized. Owing to this fact it became necessary to differentiate between the one and two surface feedings. Therefore, in order to equalize these conditions, the measurements of the one surface feeding were divided by two. Another difficulty in securing feeding measurements in the case of unsprayed twigs used as checks was encountered when the entire leaf, except the midrib and larger veins, was consumed. In such instances the outline of the leaf was nearly obliterated, thus rendering actual measurements in the ordinary way impossible. However, since the leaves of the wild cherry selected for the experiments were fairly uniform in size, this difficulty was overcome by taking the measurement of an average-size leaf and substituting it for the leaf the outline of which had been destroyed. This method gave approximately accurate results. Careful attention was given to the condition of the foliage throughout the experiments so as to supply the larvæ with palatable food at all times. It was seldom necessary, however, to renew the foliage, except for the unsprayed lots, which were quickly devoured.

Commercial lime-sulphur testing 33° Baumé was used at strengths varying from $\frac{1}{4}$ -50 to 6-50.¹ In lots 4 and 5 of Table VI home-boiled lime-sulphur testing 30° Baumé was used at the rate of 1 $\frac{1}{2}$ -50.

¹ All the strengths indicated as above signify a given quantity of poison diluted with water to make a total of 50 gallons of spray material. For example, lime-sulphur, 1 $\frac{1}{2}$ -50, means 1 $\frac{1}{2}$ gallons concentrated lime-sulphur solution diluted with water to make 50 gallons of spray material. Arsenate of lead, 2-50, means 2 pounds arsenate of lead diluted with water to make 50 gallons of spray material.

Arsenate of lead at strengths varying from $\frac{1}{2}$ -50 to 5-50 was used in comparison with the lime-sulphur solution. Arsenate of lead and lime-sulphur were also used together at various strengths (Tables I and IV). In the case of the arsenate of lead and the lime-sulphur most of the feeding was done during the first three or four days. However, in no instance was there much feeding during the first 24 hours, as the larvæ were more or less unsettled until they found a suitable place for their web. This was true on the unsprayed as well as the sprayed leaves.

It will be found in the following pages that the rate of killing is fairly uniform in all experiments. Since, however, the tests were conducted throughout the season under different climatic conditions, slight variations exist.

RESULTS.

EXPERIMENT I.

The results given in Table I are taken from an experiment to obtain data on the killing effect on the fall webworm of various chemicals combined with lime-sulphur. Lot 1 was the unsprayed check; lot 2 was sprayed with lime-sulphur alone at the strength of $1\frac{1}{2}$ -50, and lot 3 with lime-sulphur, $1\frac{1}{2}$ -50, in combination with arsenate of lead, 2-50. In the course of a few days it was observed that several larvæ on the lot sprayed with lime-sulphur were dying. The 20 larvæ of this lot were dead at the end of 13 days, as against 7 days required to kill all the larvæ with the combination of arsenate of lead and lime-sulphur. On the unsprayed lot, at the end of 72 days, 4 larvæ were recorded dead, 12 had pupated, and 4 were missing.

TABLE I.—*Tests of the killing effect on the fall webworm of lime-sulphur alone and combined with arsenate of lead.*

[Experiment started July 20, 1912, Benton Harbor, Mich., 20 larvæ in each lot.]

Larvæ dying in each lot.				Larvæ dying in each lot.			
Date of examination.	Lot 1— Check (un- sprayed).	Lot 2— Lime- sulphur, $1\frac{1}{2}$ -50.	Lot 3— Lime- sulphur, $1\frac{1}{2}$ -50, and arsenate of lead, 2-50.	Date of examination.	Lot 1— Check (un- sprayed).	Lot 2— Lime- sulphur, $1\frac{1}{2}$ -50.	Lot 3— Lime- sulphur, $1\frac{1}{2}$ -50, and arsenate of lead, 2-50.
July 22.....	1			Aug. 12.....			
23.....				14.....			
24.....			1	16.....			
25.....			7	18.....			
26.....		4	10	21.....			
27.....		3	2	23.....			
28.....		3		Sept. 2.....	1		
29.....		4		19.....	2		
30.....				30.....			
31.....		4					
Aug. 1.....				Total number dead.....	4	20	20
2.....		2		Number of days re- quired to kill.....		13	7
3.....				Square inches of foliage consumed.	243.20	0.73	0.12
4.....							
5.....							
6.....							
7.....							
8.....							
9.....							

EXPERIMENT II.

In order to obtain further data on the killing effect of lime-sulphur another experiment was started July 30, using different strengths of lime-sulphur as given in Table II.

TABLE II.—*Tests of the killing effect of lime-sulphur on the fall webworm.*

[Experiment started July 30, 1912, Benton Harbor, Mich.; 20 larvæ in each lot.]

Date of examination.	Larvæ dying in each lot.					Date of examination.	Larvæ dying in each lot.				
	Lot 1— Check (un- spray- ed).	Lot 2— Lime- sul- phur, 1½-50.	Lot 3— Lime- sul- phur, 3-50.	Lot 4— Lime- sul- phur, 6-50.	Lot 5— Arse- nate of lead, 2-50.		Lot 1— Check (un- spray- ed).	Lot 2— Lime- sul- phur, 1½-50.	Lot 3— Lime- sul- phur, 3-50.	Lot 4— Lime- sul- phur, 6-50.	Lot 5— Arse- nate of lead, 2-50.
Aug. 1.....						Aug. 14.....		2			
2.....						15.....					
3.....		2				20.....					
4.....			1	3		25.....					
5.....		1	1	5	6	29.....					
6.....				3		Total num- ber dead..					
7.....	1	1	9	8		Number days re- quired to kill..	1	20	20	20	20
8.....		3	4	1	14	Square inches foli- age consumed...	40.00	1.21	0.65	0.34	0.83
9.....		2	4								
10.....		2									
11.....		4	1								
12.....		1									
13.....		2									

¹ Arsenate of lead was used in lot 5 for comparison with the lime-sulphur solution.

In this experiment 15 days were required by lime-sulphur, 1½-50, to kill the 20 larvæ, as against 9 days required by arsenate of lead, 2-50. Twelve days were required by lime-sulphur, 3-50, while lime-sulphur, 6-50, killed the 20 larvæ in the same length of time required by arsenate of lead, 2-50. The check lot was discontinued at the end of 30 days, when 1 larva was recorded dead and 40 square inches of foliage consumed. It was found in this test that the number of square inches of foliage consumed decreased about one-half as the strength of the lime-sulphur was doubled, the largest amount being 1.21 square inches. The amount consumed on the arsenate-of-lead lot was 0.83 of a square inch.

EXPERIMENT III.

In Table III are shown the comparative results of a dosage test consisting of seven different strengths of lime-sulphur varying from ½-50 to 6-50, and four different strengths of arsenate of lead varying from ½-50 to 5-50.

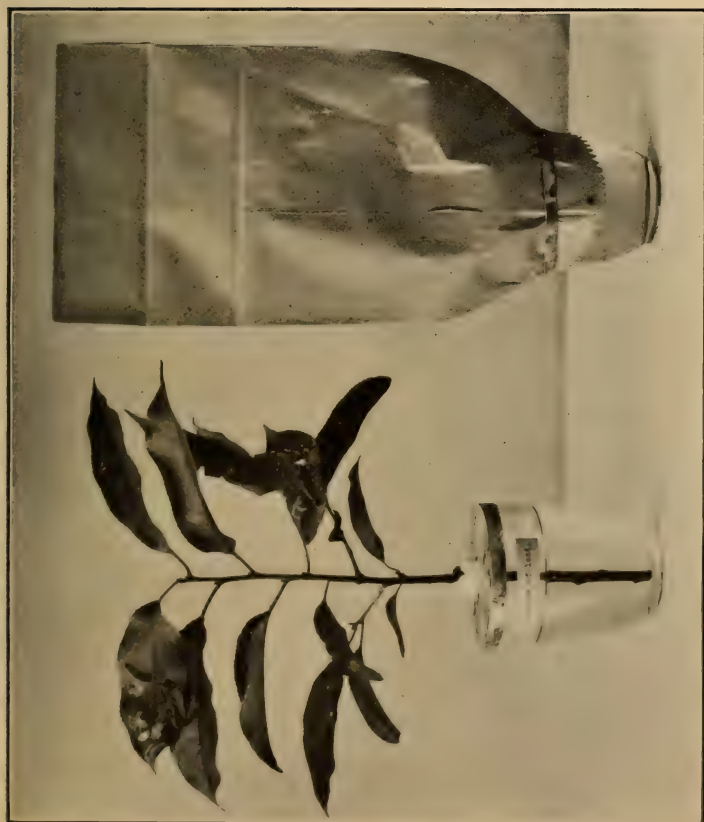


FIG. 1.—AT LEFT, SPRAYED TWIG OF WILD CHERRY, SHOWING LARVÆ OF THE FALL WEBWORM (*HYPHANTHRIA CUNEÆ*) FEEDING ON LEAVES; AT RIGHT, SAME, COVERED WITH PAPER BAG TO PREVENT ESCAPE OF LARVÆ. (ORIGINAL.)



FIG. 2.—UNSPRAYED TWIG OF WILD CHERRY UPON WHICH FALL WEBWORMS HAVE BEEN FEEDING FOR SOME TIME; FOR COMPARISON WITH SPRAYED TWIG. (ORIGINAL.)

METHOD OF TESTING LIME-SULPHUR AS A STOMACH POISON AGAINST THE FALL WEBWORM.

TABLE III.—*Tests of the killing effect on the fall webworm of lime-sulphur in comparison with arsenate of lead.*

[Experiment started August 8, 1912, Benton Harbor, Mich., 20 larvæ in each lot.]

Date of examination.	Larvæ dying in each lot.											
	Lot 1— Check (un- spray- ed).	Lot 2— Lime- sul- phur, ½-50.	Lot 3— Lime- sul- phur, 1-50.	Lot 4— Lime- sul- phur, 1½-50.	Lot 5— Lime- sul- phur, 2-50.	Lot 6— Lime- sul- phur, 3-50.	Lot 7— Lime- sul- phur, 5-50.	Lot 8— Lime- sul- phur, 6-50.	Lot 9— Arse- nate of lead, ½-50.	Lot 10— Arse- nate of lead, 1-50.	Lot 11— Arse- nate of lead, 2-50.	Lot 12— Arse- nate of lead, 5-50.
Aug. 10.....								2		2	8	4
12.....							1	3		2	11	15
14.....		1	4	5	2	3	6	11	1	10	1	1
16.....		3	8	13	6	6	6	4	11	2		
18.....		2	8	2		8	11	7	3	4		
20.....		8			4				4			
22.....		6							1			
Sept. 2.....	2											
10.....	3											
Oct. 19.....	2											
Total number dead.....	7	20	20	20	20	20	20	20	20	20	20	20
Number days required to kill.....		14	10	10	12	10	10	8	14	10	6	6
Square inches of foliage consumed.....	119.00	3.92	0.36	0.17	1.01	0.81	0.73	0.26	2.38	1.98	0.11	0.10

It will be noted that lime-sulphur, ½-50, killed the 20 larvæ in 14 days, the same length of time required by arsenate of lead, ½-50. Also lime-sulphur, 1-50, killed the larvæ in the same length of time as arsenate of lead 1-50, the time required being 10 days. However, in both instances the arsenate of lead killed more rapidly in the beginning than the lime-sulphur. Eight days were required by lime-sulphur, 6-50, to kill the 20 larvæ as against 6 days required by arsenate of lead, 5-50. The amount of feeding varied somewhat in this experiment, the largest amount on the sprayed lots being 3.92 square inches where lime-sulphur, ½-50 was used, and the smallest amount being 0.10 of a square inch in lot 12 which was sprayed with arsenate of lead, 5-50.

EXPERIMENT IV.

The object of experiment IV was to obtain data on the relation of the killing effect of arsenate of lead alone and combined with lime-sulphur, and to obtain, if possible, data on the effect the addition of one to the other has upon the rapidity of killing. Lime-sulphur alone was used at four different strengths, and also was combined at the same rates with arsenate of lead, 2-50. The lime-sulphur strengths employed were ¼-50, ¾-50, 1½-50, and 3-50. Arsenate of lead, alone, was tried out at strengths of ½-50, 1-50, 2-50, 3-50, and 5-50, and also at the same strengths was combined with lime-sulphur, 1½-50. The results are given in Table IV.

TABLE IV.—*Tests of the killing effect on the fall webworm of lime-sulphur and arsenate of lead, alone and combined.*

[Experiment started Aug. 19, 1912, Benton Harbor, Mich., 20 larvæ in each lot.]

Date of examination.	Larvæ dying in each lot.									
	Lot 1— Check (un- sprayed).	Lot 2— Lime- sulphur, $\frac{1}{4}$ -50.	Lot 3— Lime- sulphur, $\frac{3}{4}$ -50.	Lot 4— Lime- sulphur, $1\frac{1}{2}$ -50.	Lot 5— Lime- sulphur, 3-50.	Lot 6— Arse- nate of lead, $\frac{1}{2}$ -50.	Lot 7— Arse- nate of lead, 1-50.	Lot 8— Arse- nate of lead, 2-50.	Lot 9— Arse- nate of lead, 3-50.	Lot 10— Arse- nate of lead, 5-50.
Aug. 21.....			1		3		3	4	5	12
23.....		1	2	2	2	2	10	2	13	8
25.....		2	1	8	9	8	7	14	2	
27.....		8	7	10	6	7				
29.....		8	7			3				
31.....		1	2							
Sept. 2.....										
4.....										
6.....										
8.....										
10.....										
15.....		3								
Oct. 3.....		5								
Total num- ber dead....	8	20	20	20	20	20	20	20	20	20
Number days required to kill....		12	12	8	8	10	6	6	6	4
Square inches of foliage consumed....	72.00	3.51	2.87	0.17	0.49	2.44	0.36	0.57	0.24	0.02

Date of examination.	Larvæ dying in each lot.							
	Lot 11— Lime- sulphur, $1\frac{1}{2}$ -50; arsenate of lead, $\frac{1}{2}$ -50.	Lot 12— Lime- sulphur, $1\frac{1}{2}$ -50; arsenate of lead, 1-50.	Lot 13— Lime- sulphur, $1\frac{1}{2}$ -50; arsenate of lead, 2-50.	Lot 14— Lime- sulphur, $1\frac{1}{2}$ -50; arsenate of lead, 5-50.	Lot 15— Arsenate of lead, 2-50; lime- sulphur, $\frac{1}{4}$ -50.	Lot 16— Arsenate of lead, 2-50; lime- sulphur, $\frac{3}{4}$ -50.	Lot 17— Arsenate of lead, 2-50; lime- sulphur, $1\frac{1}{2}$ -50.	Lot 18— Arsenate of lead, 2-50; lime- sulphur, 3-50.
Aug. 21.....			3	10	9	5	1	6
23.....	2	14	9	10	9	11	6	9
25.....	8	4	7		2	4	13	5
27.....		2	1					
29.....	4							
31.....								
Sept. 2.....								
4.....								
6.....								
8.....								
10.....								
15.....								
Oct. 3.....								
Total number dead.....	20	20	20	20	20	20	20	20
Number days required to kill....	10	8	8	4	6	6	6	6
Square inches of foliage consumed....	0.52	0.02	0.28	0.07	0.30	0.19	0.06	0.22

None of the larvæ on the unsprayed lot died until September 15, 27 days after the experiment was started. On October 3 the records of this lot showed 8 dead, 6 pupated, and 6 missing. Lime-sulphur alone, $\frac{1}{4}$ -50, and likewise $\frac{3}{4}$ -50, killed all the larvæ in 12 days, while the time required by strengths of $1\frac{1}{2}$ -50 and 3-50 was 8 days in each case, the rapidity of killing being somewhat greater with the latter strength. Arsenate of lead alone, $\frac{1}{2}$ -50, killed the 20 larvæ in 10 days, or 2 days more than was required by lime-sulphur, $1\frac{1}{2}$ -50. Arsenate

of lead, 1-50, 2-50, and 3-50, each killed the larvæ 2 days sooner than that required by lime-sulphur, 1½-50. Lime-sulphur, 1½-50, when added to the various strengths of arsenate of lead did not appreciably affect the rate of killing of the arsenate of lead. The amount of feeding was reduced in all cases, excepting that of the strongest solution, lot 14, by the addition of lime-sulphur.

On the lots sprayed with lime-sulphur, ¼-50, ¾-50, 1½-50, and 3-50, combined with arsenate of lead, 2-50, there was no difference in the length of time required to kill the larvæ, 6 days being required in all cases. The same number of days was required by arsenate of lead alone, 2-50, but the rapidity of killing was somewhat increased by the addition of lime-sulphur.

EXPERIMENT V.

In an experiment to obtain data on the sticking qualities of various sprays, three lots of the regular orchard demonstration strength of lime-sulphur, 1½-50, were used. The three lots were thoroughly sprayed and allowed to dry. One lot was then washed for 15 minutes under a shower bath, by placing the twig just above the floor in an inclined position, allowing the water to fall upon it. Another lot was washed 30 minutes in the same manner, while the third lot remained unwashed.

The same procedure was carried out on three lots of arsenate of lead, 2-50. After the twigs were again thoroughly dry 20 larvæ were placed on each. The results of this experiment are to be found in Table V.

TABLE V.—*Tests of the killing effect of lime-sulphur in comparison with arsenate of lead after washing of each.*

[Experiment started August 4, 1912, Benton Harbor, Mich., 20 larvæ in each lot.]

Date of examination.	Larvæ dying in each lot.						
	Lot 1— Check (un- sprayed).	Lot 2— Lime- sulphur, 1½-50; not washed.	Lot 3— Lime- sulphur, 1½-50; washed 15 minutes.	Lot 4— Lime- sulphur, 1½-50; washed 30 minutes.	Lot 5— Arsenate of lead, 2-50; not washed.	Lot 6— Arsenate of lead, 2-50; washed 15 minutes.	Lot 7— Arsenate of lead, 2-50; washed 30 minutes.
Aug. 7.....					1		
9.....					7	2	
11.....		2			12	4	
13.....		2		2		5	1
15.....		12	9	8		9	2
17.....	1	4	7	9			7
19.....			2				4
21.....							4
29.....	2						
Sept. 9.....	3						
19.....	1						
Total number of dead....	7	20	20	20	20	20	18
Number of days required to kill.		13	15	13	7	11	17
Square inches of foliage consumed.....	111.00	0.82	1.56	0.84	0.38	1.79	5.00

1 2 escaped.

The washing made practically no difference in the killing effect of the lime-sulphur spray, the time of killing varying from 13 to 15 days, and the amount of foliage consumed varying from 0.82 to 1.56 square inches. In the case of arsenate of lead, however, the killing effect was considerably retarded. The length of time required to kill all the larvæ when the foliage was unwashed was 7 days; when washed 15 minutes, 11 days; when washed 30 minutes, 17 days. The amount of feeding was 0.38, 1.79, and 5 square inches, respectively.

EXPERIMENT VI.

To compare the killing effect of commercial lime-sulphur and home-boiled lime-sulphur, an experiment was conducted in which two lots of each kind were used at the strength of $1\frac{1}{2}$ -50. The commercial products tested 33° Baumé and the home-boiled 30° Baumé. The results are shown in Table VI.

TABLE VI.—*Tests of the killing effect on the fall webworm of lime-sulphur, commercial and home-boiled.*

[Experiment started Aug. 27, 1912, Benton Harbor, Mich., 20 larvæ in each lot.]

Date of examination.	Larvæ dying in each lot.				
	Lot 1 (20 larvæ)— Check (un- sprayed).	Lot 2 (20 larvæ)— Commercial lime-sulphur, $1\frac{1}{2}$ -50.	Lot 3 (20 larvæ)— Commercial lime-sulphur, $1\frac{1}{2}$ -50.	Lot 4 (20 larvæ)— Home-boiled lime-sulphur, $1\frac{1}{2}$ -50.	Lot 5 (20 larvæ)— Home-boiled lime-sulphur, $1\frac{1}{2}$ -50.
Aug. 30.....				1	
Sept. 1.....		6	4	3	5
4.....		7	9	7	6
6.....		7	6	6	9
9.....			1	3	
19.....	1				
Oct. 13.....	5				
Total number dead.....	6	20	20	20	20
Number of days required to kill.....		9	12	12	9
Square inches of foliage consumed.....	116.00	1.19	1.28	3.05	4.38

It was found that the commercial and the home-boiled lime-sulphur killed all the larvæ in the same average length of time. However, the rapidity of killing was slightly greater, and the amount of foliage consumed less, where the commercial material was used, due probably to the fact that the commercial solution was somewhat stronger, which the Baumé tests would indicate.

EXPERIMENT VII.

Lime-sulphur, $1\frac{1}{2}$ -50, was tried out on a limited number of pear-slug larvæ (*Eriocampoides cerasi* L.), since only a few were available for this test. As in all the experiments, the insects were not placed upon the leaves until the spray had thoroughly dried. The results are shown in Table VII.

TABLE VII.—*Tests of the killing effect of lime-sulphur on the pear slug (Eriocampoides cerasi L.).*

[Experiment started Aug. 24, 1912, Benton Harbor, Mich., 6 larvæ in each lot.]

Date of examination.	Larvæ dying in each lot.		
	Lot 1 (6 larvæ)—Check (unsprayed).	Lot 2 (6 larvæ)—Lime-sulphur, 1½-50.	Lot 3 (6 larvæ)—Lime-sulphur, 1½-50.
Aug. 25.....		3	
26.....		2	4
27.....		1	2
28.....			
29.....			
Total number dead...	0	6	6
Number of days required to kill.....		3	3
Square inches of foliage consumed.....	1.69	0.08	0.05

Three days were required to kill all the larvæ on the sprayed lots. At the end of five days, when the experiment was closed, the larvæ on the unsprayed lot were apparently in a normal condition.

MISCELLANEOUS TESTS.

Preparations were made to conduct a number of feeding experiments on the killing effect of lime-sulphur on the second brood of codling-moth larvæ (*Carpocapsa pomonella* L.). But since a sufficient number of larvæ was not obtainable, owing to the small size of this brood appearing in Michigan, no satisfactory tests could be made. Neither were there any tests with lime-sulphur alone made against this insect in the field. However, in the case of a plat of Ben Davis apples, sprayed three times with lime-sulphur, 1-50, and 10 per cent kerosene emulsion, no arsenical being used, the total percentage of windfalls and picked fruit free from the codling moth was 90.18, as against 41.31 per cent of fruit free from this insect on the unsprayed plat. Lime-sulphur, 1-50, and fish-oil soap, 7 pounds to 50, without an arsenical, in the same orchard held the codling moth to 88.19 per cent of sound fruit. The effectiveness of lime-sulphur alone in controlling the codling moth and numerous other insects will be further tested during the season of 1913.

A few laboratory tests were made of the killing effect of Bordeaux mixture, 3-4-50, on the fall webworm and about as effective results were obtained as from lime-sulphur solutions.

Self-boiled lime-sulphur, 8-8-50, the preparation used for spraying peaches in foliage, was tried against the fall webworm without any killing effect. Sulphur alone, 8-50, and lime alone, 8-50, likewise were ineffective.

CONCLUSIONS.

The foregoing tests of lime-sulphur wash against the larvæ of the fall webworm show that this preparation has decided value as a stomach poison. It is considered extremely probable that caterpillars of many species of insects, and perhaps mandibulate insects in general, will be similarly susceptible. As shown by the data given, lime-sulphur, $1\frac{1}{2}$ -50, while slower in killing effect than arsenate of lead, 2-50, nevertheless compares favorably with this strength of arsenical. A comparison, however, of leaf-areas eaten by larvæ subjected to lime-sulphur and arsenate of lead, respectively, shows that the lime-sulphur, especially at increased strengths, compares quite favorably with the arsenical in reducing feeding by the caterpillars.

This action of lime-sulphur as a stomach poison probably accounts for the reported practical control of the codling moth in orchards treated with lime-sulphur alone, and furnishes an additional reason for its employment as a fungicide.

Experiments in progress by the Bureau of Entomology during the past two years warrant the statement that entirely satisfactory results in controlling the codling moth in orchards may be obtained with lime-sulphur wash combined with reduced strengths of arsenate of lead.

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U. S. DEPARTMENT OF AGRICULTURE,
BUREAU OF ENTOMOLOGY—BULLETIN No. 116, Part V.

L. O. HOWARD, Entomologist and Chief of Bureau.

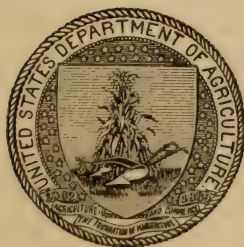
PAPERS ON DECIDUOUS FRUIT INSECTS
AND INSECTICIDES.

THE FRUIT-TREE LEAF-ROLLER.

BY

JOHN B. GILL,
Entomological Assistant.

ISSUED MARCH 12, 1913.



WASHINGTON:
GOVERNMENT PRINTING OFFICE.
1913.

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ment of insecticide act, 1910.*

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PAPERS ON DECIDUOUS FRUIT INSECTS AND INSECTICIDES.

THE FRUIT-TREE LEAF-ROLLER.

*(Archips argyrospila Walk.)*By JOHN B. GILL,
Entomological Assistant.

INTRODUCTION.

Until quite recently the fruit-tree leaf-roller (*Archips argyrospila* Walk.) has been looked upon as an insect of only minor importance to cultivated crops. During the past few years, however, it has become unusually abundant and has caused considerable loss to fruit growers in certain sections, notably in Colorado and New Mexico and in New York State. The most serious outbreaks have appeared in Colorado in Fremont, Pueblo, and Montezuma Counties, and in New Mexico in San Juan and Rio Arriba Counties. The investigations, detailed in this paper, have been confined for the most part to the infestations at Canon City, Colo., and Espanola, N. Mex. In the former place the damage has been large, as the insect has appeared in serious numbers in about 1,500 acres of bearing orchards in what is locally known as the Lincoln Park section, and it is also spreading rapidly into adjacent fruit districts. If not checked the amount of loss that will be occasioned by its attacks in the future will probably be much greater than in the past. At Espanola, N. Mex., a comparatively small fruit belt, the infestation has not been so serious. The damage incurred by the leaf-roller has varied from 25 to 90 per cent of the entire fruit crop, depending on the measures of control adopted, the abundance of the "worms," and the kind or variety of fruit attacked. In unsprayed orchards the writer has seen the entire fruit crop ruined by the larvæ, and the trees completely defoliated so that not a green leaf could be noticed. When trees are so defoliated it is hardly possible for them to produce fruit buds for the following season.

In speaking of the appearance of the fruit-tree leaf-roller in New York Prof. G. W. Herrick says:

In the spring of 1911 the larvæ of this insect appeared in enormous numbers in the orchard of Mr. W. O. Page at Bethany Center, N. Y., and to a considerable extent in neighboring orchards. Moreover, the apple leaf-roller was not confined by any means to a small and limited area, but the larvæ were found in many orchards of New York in varying numbers.

A few years ago the Missouri fruit growers suffered considerable loss on account of this same leaf-roller.

Because of the increasing economic importance of this insect the Bureau of Entomology started investigations in 1911 at Espanola, N. Mex., with which work the writer was charged, under the direction of Mr. A. L. Quaintance. During the season of 1911 little was accomplished owing to the stress of work along other lines in fruit sections that were not troubled with the leaf-roller. On account of the seriousness of the outbreak at Canon City, Colo., it was decided to maintain a temporary field station at that place during 1912 for conducting orchard spraying experiments and life-history studies of the insect. The investigations during this time have shown the value of certain practical measures for the control of this pest, and have resulted in the obtaining of considerable data on its life history. The object of the present publication is to give as much information as is now available about the leaf-roller and methods for its control.

The writer wishes especially to thank the orchardists of Colorado and New Mexico who have assisted in this work.

HISTORY.

The fruit-tree leaf-roller was first described by Walker in 1863 under the name *Retinia argyrospila*, from material collected in Georgia. In 1869 it was first recognized in this country by Robinson as doing damage, and was redescribed as a new species, *Tortrix furvana*. The following year (1870) Packard described it as a new species, naming it *Tortrix v-signatana* and giving its distribution as "Maine to Georgia and Texas and Missouri," and its food plants as black walnut, maple, cherry, and horse-chestnut. Packard also gave a description of its life history and food plants in the Fifth Report of the United States Entomological Commission, pages 192, 195, 329, 425, 530, and 655. In an article in *Insect Life*, Volume III, page 19, by Riley and Howard, this species is mentioned as a rose pest. Lintner included it in his Eleventh Report of the State Entomologist of New York (1896) as one of the 356 species of insects that were enemies of the apple. Gillette, in Bulletin No. 26 of the Division of Entomology, United States Department of Agriculture (1900), mentions it as a general feeder, and in the Thirteenth Annual Report of the Colorado Experiment Station (1900), page 123, it is also mentioned. In Bulletin No. 27 of the Division of Entomology (1901), page 88, Chittenden refers to it as affecting the rose. Holland, in "The Moth Book," page 422, plate 48, fig. 34, discusses this species, and it is included in Dyar's List of North American Lepidoptera, page 480, with its distribution limited to California and Colorado. In Bulletin No. 38 of the Division of Entomology, page 36, Mr. A. N. Caudell gives an account of it as infesting ash in Colorado. Horsfall,

in Bulletin No. 9 of the Missouri State Fruit Experiment Station, page 22 (1903), states that it was very destructive in 1901. In Bulletins Nos. 94, pages 9-11, and 114, page 7, of the Colorado Experiment Station, Gillette again discusses this species. The most complete account is by Stedman in Bulletin No. 71, Missouri Agricultural Experiment Station. In the last edition (1909) of "Insects of New Jersey," by Smith, it is included and mentioned as a very general feeder throughout the State. An article by Herrick appeared in the Rural New Yorker, March 2, 1912, page 263, in which it was discussed as a "new pest of the apple in New York." The same writer, in Bulletin 311 of the Cornell University Agricultural Experiment Station, gives a full account of the species, as based on its occurrence in New York State.

The above includes all the important articles on this insect, so far as the writer has been able to determine.

DISTRIBUTION.

The fruit-tree leaf-roller is generally distributed throughout the United States. Stedman, in Bulletin No. 71 of the Missouri Experiment Station, page 7, states that "this insect is found in damaging numbers practically all over the United States from Maine to the Gulf and westward to the Pacific coast and up as far as Oregon." Packard, in 1870, gave its distribution as "Maine to Oregon and Texas and Missouri." Holland gives its range as "Atlantic to Pacific." So far as the writer has been able to determine from literature on hand, the species has been definitely recorded from New York, New Jersey, Georgia, Missouri, Texas, Colorado, and California. The writer reports it in New Mexico from Espanola, Santa Fe, and Taos. It is also reported from Riverside, N. Mex. In Colorado it is recorded from Canon City, Vineland, Avondale, Cortez, Olathe, Fort Collins, Brewster, Penrose, and Garden Park. The writer has been unable to get a list of specific localities for other States.

Although widely distributed throughout the United States, it ranks as a pest at the present time in only a few localities in Colorado, New Mexico, and New York, where conditions seem to have been favorable, for some reason or other, for it to appear in enormous numbers.

FOOD PLANTS.

The insect is a very general feeder and consequently has been reported on a large number of plants. It appears at times in injurious numbers on apple, pear, plum, cherry, apricot, quince, peach, rose, currant, raspberry, and gooseberry. It has also been recorded feeding more or less on black walnut, horse-chestnut, soft maple, hickory, oak, elm, wild cherry, ash, honey locust, box-elder, sassafras,

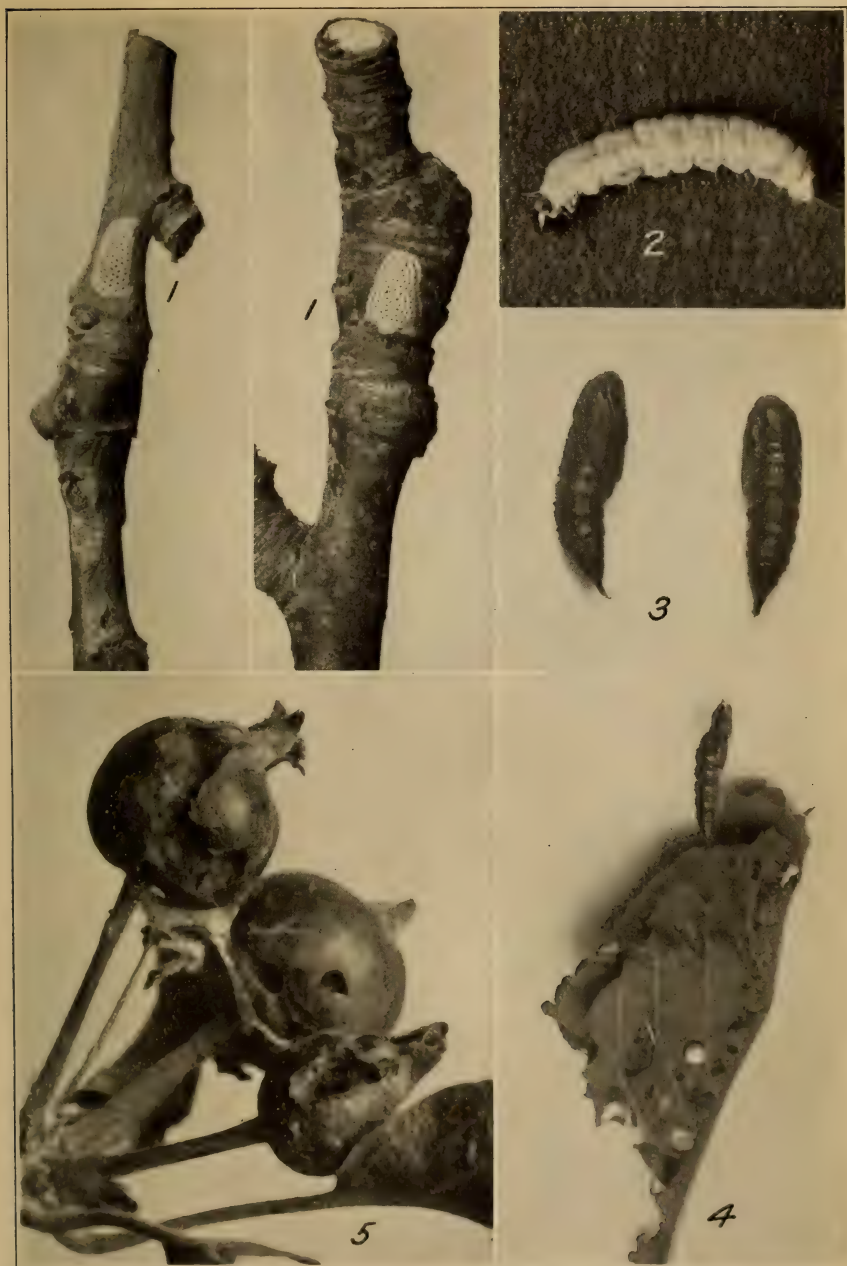
hazelnut, and osage orange. In addition to the above the writer has observed the larvæ feeding on grape, blackberry, cottonwood, Carolina poplar, basswood, cedar, lilac, Virginia creeper, snowball, hop-vines, and oats, wheat, alfalfa, red clover, onions, peas, beans, radishes, and rhubarb that were growing in or adjacent to badly infested orchards. This species appears to be able to thrive on the foliage of almost any plant.

CHARACTER OF INJURY.

As the manner in which the larvæ attack the various host plants differs to a certain degree, it seems advisable to give a rather full discussion of the more important injuries, especially those occurring on fruit trees.

In the spring, just as the buds are bursting, the larvæ begin to gnaw their way out of the eggshells and hard protective covering of the egg masses. (Pl. XII, fig. 1.) The young caterpillars at once migrate to the developing buds and begin feeding on the unfolding leaves. At first they eat small inconspicuous holes in the unfolded leaves, and at this time the average orchardist is not aware of their presence. After feeding in this manner for a few days the larvæ become quite conspicuous as they begin to spin fine silken threads from leaf to leaf. Eventually they fold or roll up a single leaf or a cluster of leaves and here they feed for the greater part of the time, though occasionally straying out of their concealment to feed in the open. (Pl. XIII, fig. 1.) Before the blossoms are fully out, or even before the cluster buds have separated, the "worms" can be observed webbing them together and feeding voraciously. Very often serious injury results before the trees come into blossom. Later in the season the webs produced by the larvæ are often quite conspicuous, as is shown in Plate XV.

As soon as the young fruit has set the larvæ cease feeding on the foliage to a large extent, and now fasten one or more leaves to the fruit and within this protection feed greedily, at first eating the skin only, but shortly consuming the pulp and the seeds or stone, depending on the kind of fruit attacked. (Pl. XIII, fig. 2.) Sometimes young apples are completely devoured except for the stem and a portion of the calyx end. Cases have been noticed where the larvæ have completely gnawed through the stems, thus causing the fruit to fall to the ground or remain suspended within the feeding nest. Damage done to apples as well as other fruits is usually so severe that the fruit can not outgrow the injury, thus causing a large percentage of unmerchantable or second-class fruit at picking time. Much fruit is also caused to fall prematurely on account of the serious injury inflicted on it when young. The writer has seen several orchards



STAGES AND WORK OF THE FRUIT-TREE LEAF-ROLLER (*ARCHIPS ARGYROSPILA*).

FIG. 1.—HATCHED EGG MASSES ON APPLE TWIGS. FIG. 2.—FULL-GROWN LARVA. FIG. 3.—PUPÆ. FIG. 4.—COCOON IN APPLE LEAF AND EMPTY PUPAL CASE. FIG. 5.—YOUNG APPLES INJURED BY LARVÆ. FIGS. 1, 2, 3, MUCH ENLARGED. (ORIGINAL.)

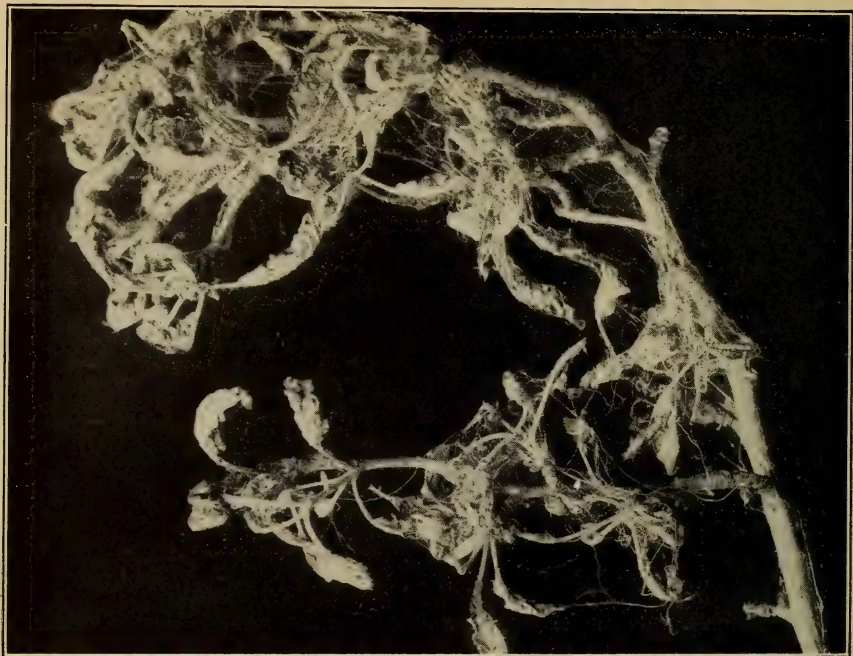


FIG. 1.—APPLE BRANCH, SHOWING WEBBING AND INJURY TO FOLIAGE BY LARVÆ.
(ORIGINAL.)



FIG. 2.—APPLES INJURED BY LARVÆ. (ORIGINAL.)
WORK OF THE FRUIT-TREE LEAF-ROLLER.



APPLE ORCHARD AT CANON CITY, COLO., DEFOLIATED BY THE FRUIT-TREE LEAF-ROLLER. (ORIGINAL.)



EXCESSIVE WEBBING BY LARVÆ OF THE FRUIT-TREE LEAF-ROLLER. (ORIGINAL.)

at Canon City, Colo., where the entire apple crop was absolutely ruined and where the larvæ had defoliated the trees so completely that not a green leaf could be seen. (Pl. XIV.) At Espanola, N. Mex., fully 75 per cent of the fruit crop in certain apple orchards has been destroyed by these leaf-roller "worms," which have besides caused serious injury to the foliage. Similar conditions have been seen at Vineland and Avondale, Colo.

The injury to pears is quite similar to that of the apple, but not so extensive. The writer, in talking with orchardists at Espanola, N. Mex., in reference to the amount of injury to pears that had been sprayed twice with arsenate of lead, was informed that one-fourth to one-half of the crop was damaged to such an extent that it could not be packed. Even a very slight feeding on the pear when young often results in an ill-formed specimen when mature. Pear trees are not usually defoliated by the leaf-roller, even if not sprayed. The writer has, however, observed a few instances where they were completely defoliated in a very badly infested district.

In case of stone fruits, such as plum, apricot, and cherry, much of the pulp, as well as occasionally a part of the stone, is eaten, except with the cherry, which seems to escape injury to the seed. Cherry and plum trees are sometimes entirely defoliated. According to reports from Riverside, N. Mex., during 1909 and 1910 the entire peach crop was destroyed by this pest. During the past two seasons the writer has failed to find a single instance where a peach orchard has been injured very much. The nature of the injury to the peach is a slight feeding on the surface, and the larvæ seem never to have eaten into the pulp as far as the stone.

The injury on small fruits, such as raspberries, currants, gooseberries, etc., is often quite serious, as the larvæ not only feed on the foliage but also eat into the fruits. The larvæ occasionally feed on the foliage of the grape. Of the shade and forest trees that are attacked the worst injury usually results on the elm, on which the leaves are often badly eaten. The damage noticed on truck crops, oats, wheat, alfalfa, and red clover has been a slight feeding on the leaves. The larvæ, however, on one occasion were noticed eating their way into the tops of onion plants that were growing between rows of apple trees that had been defoliated by this species. Another case at the same place was noticed where a small cedar tree was nearly stripped of its leaves by these larvæ, and the tree was covered by webs. Roses are seriously injured at times, as the larvæ not only feed on the foliage but gnaw into the flower buds and prevent their proper development.

DESCRIPTION OF STAGES.

THE ADULT.

This leaf-roller was first characterized and named in 1863 by Walker in the Catalogue of the British Museum, volume 28, page 373, as *Retinia argyrospila*. The original description is as follows:

Female. Reddish, cinereous beneath. Head ochraceous; palpi porrect, broad, extending very little beyond the head; third joint extremely short. Abdomen cinereous, extending a little beyond the hind wings. Forewings rectangular at the tips, with several transverse slightly undulating black streaks; space along the interior border and some incomplete irregular bands silvery cinereous; costa straight, with three large silvery white marks, exterior border slightly oblique hindward. Hind wings brownish cinereous. Length of the body $3\frac{1}{2}$ lines; of the wings 10 lines.

a. Georgia. From Mr. Milne's collection.

The moths measure from 17 to 23 mm. across the expanded wings. The length of the body varies from 8 to 10 mm. There is a wide variation in color. The general color of the forewings varies from a light brown to a cinnamon or rusty brown. The markings on the forewings also show a variation in size, pattern, and color. Ordinarily each forewing has three whitish markings. The hind wings are without markings and are of a uniform ashy-gray color. (Pl. XVI, fig. 2, at left.)

THE EGG.

The eggs are deposited in slightly convex, oval masses or patches which vary in color from a light gray to a dark brown. The egg masses are covered by a hard protective coating. The size of the masses is variable. The average for 20 was found to be 5.1 by 2.6 mm. The average number of eggs per mass is about 90. The individual egg is quite small and is a little more than twice as long as wide. The eggs are packed in the mass very tightly. A longitudinal section of an entire egg mass presents a honeycombed arrangement. (Pl. XII, fig. 1; Pl. XVI, figs. 1, 3.)

THE LARVA.

When newly hatched the larva measures about 1.5 mm. in length and is pale yellowish green, with the head and thoracic shield dark brown or nearly black. At this time the thoracic legs are nearly black, while the prolegs are of the same general color as the body. As the larva develops the color of the head, thoracic shield, and legs gradually changes to a light brown and the body takes on a darker shade of green. Before pupating the thoracic shield and legs of the larva take on an olive-green tinge, slightly darker than the rest of the body, which is now a light green. The larva is sparingly clothed with short hairs, which arise from rather inconspicuous tubercles. The full-grown larvæ measure from 16 to 23 mm. in length and from 2 to 2.2 mm. in greatest width. The average size for 10 larvæ was found to be 20.3 by 2.04 mm. (Pl. XII, fig. 2.)

THE PUPA.

The pupa is rather variable in size. The average dimensions of 10 pupæ were found to be 10.3 by 3.1 mm. The general color of the pupa when first formed is an olive green, but later changes to a light brown and finally to a dark brown. The entire ventral surface, including the head and thoracic regions, is of a dark-brown color and the remainder of the pupa is of a much lighter brown. The wing sheaths are rather broad, extending about one-half the total length of the pupa. Just ventral to the spiracles on each side of the abdomen are two short setæ. On each abdominal segment, from the third to the last, on the ventral portion is a pronounced chitinous serrated ridge. The second abdominal segment has traces of one of these ridges. The posterior end of the pupa is supplied with a well-developed cremaster. (Pl. XII, fig. 3.)

LIFE HISTORY AND HABITS.

The life-history records were obtained at Canon City, Colo., during the season of 1912 in an open-air insectary or shelter in which glass jars were used as rearing cages. In all cases apple foliage was used as food for the larvæ.

LARVAL STAGE.

The hatching of the larvæ extended over a period of 12 days. The earliest larvæ hatched April 27 and the latest ones on May 9. As soon as the larvæ hatch from the eggs they gnaw their way through the protective covering which the females deposit over the egg masses during oviposition. The duration of the larval period showed a considerable variation. The number of days spent in the larval stage for 203 individuals is shown in the following table:

TABLE I.—Length of larval stage of the fruit-tree leaf-roller, Canon City, Colo., 1912.

Date larvæ hatched.	Number of larvæ under ob- serva- tion that trans- formed to pupæ.	Larvæ pupating in specified days from time of hatching.													Total num- ber of days.
		24	25	26	27	28	29	30	31	32	33	34	35		
Apr. 27	21							8	5	6	1	1			
do.	23						2	7	7	3	2	1	1		
Apr. 29	20					1	5	7	3	2	1	1			
May 2	20			3	5	5	2	3	2						
May 3	23		2	9	4	5	2	1							
May 4	23	1	7	9	4		1	1							
May 7	25	2	5	8	7	2	1								
May 8	23	1	4	8	5	3	1	1							
May 9	25	2	5	7	5	4	1	1							
	203	6	23	44	30	20	15	29	17	11	4	3	1	5,696	

Average time for all individuals, 28.05 days.

The time required for the larvæ to reach maturity was determined for 203 individuals, as is shown in Table I. The average time for all larvæ was found to be 28.05+ days, the maximum being 35 days and the minimum 24 days.

The length of the larval period for 1912 was doubtless longer than during a normal season. The weather conditions that prevailed throughout the spring of 1912 were to some degree exceptional. During the larval development from May 4 to 17, inclusive, the weather was exceptionally cool, the maximum temperatures for these days ranging from 38° to 76° F.

In the rearing cages the larvæ, when full grown, invariably transformed into pupæ in the rolled-up leaves upon which they had been feeding. In a few cases larvæ were seen pupating on the bottom of the cages. In the field larvæ usually change to pupæ in the rolled-up leaves. In a few instances they have been observed making the transformation on the bark of the trees, where no protection was afforded the pupæ.

PUPAL STAGE.

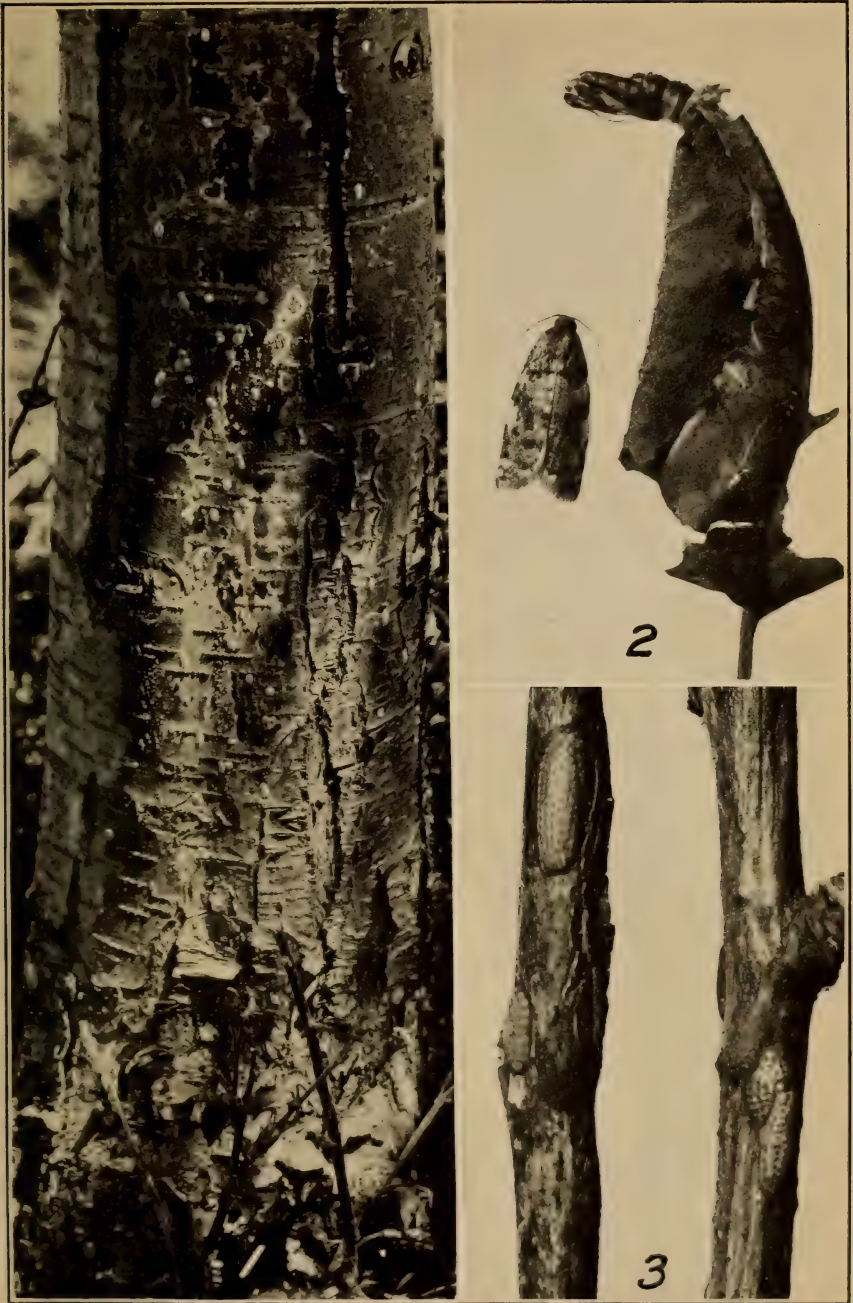
The length of the pupal period for 128 individuals is shown in the following table:

TABLE II.—*Length of pupal stage of the fruit-tree leaf-roller, Canon City, Colo., 1912.*

Date larvæ pupated.	Number of pupæ under ob- servation from which moths emerged.	Moths emerging in specified days from date of pupation.							Total num- ber of days.
		9	10	11	12	13	14	15	
May 28	6	---	1	4	1	---	---	---	---
May 29	6	---	2	3	1	---	---	---	---
May 30	17	2	2	6	5	2	---	---	---
May 31	10	1	3	3	2	1	---	---	---
June 1	5	---	2	1	2	---	---	---	---
June 2	7	1	3	2	1	---	---	---	---
June 3	18	2	3	6	5	1	1	---	---
June 4	15	2	4	5	2	1	1	---	---
June 5	10	---	1	1	2	3	2	1	---
June 6	10	---	1	2	3	2	1	1	---
June 7	2	---	---	1	---	1	---	---	---
June 8	4	---	---	3	1	---	---	---	---
June 9	3	---	---	2	1	---	---	---	---
June 10	8	---	2	3	2	1	---	---	---
June 13	7	---	3	4	---	---	---	---	---
	128	8	27	46	28	12	5	2	1,440

Average time for all individuals, 11.25 days.

The earliest larvæ to pupate were observed on May 28, and the latest ones on June 13. The days spent in the pupal state varied from 9 to 15 days, the average for 128 individuals being 11.25 days as is shown in Table II.



STAGES OF THE FRUIT-TREE LEAF-ROLLER.

FIG. 1.—EGG MASSES ON TRUNK OF APPLE TREE. FIG. 2.—MOTH AND EXTRUDED PUPAL CASE. FIG. 3.—UNHATCHED EGG MASSES ON APPLE TWIGS. FIG. 1, MUCH REDUCED; FIGS. 2, 3, MUCH ENLARGED. (ORIGINAL.)

In the orchard the first pupæ were observed on June 1 and the maximum period of pupation was reached from about June 12 to June 20. Pupæ could, however, be found in the field as late as July 10.

Just before the emergence of the adult the pupa wriggles out of its loosely woven cocoon (Pl. XII, fig. 4; Pl. XVI, fig. 2, at right) for a short distance. The posterior end of the pupa is provided with three pairs of hooks, which are known as the cremaster, and these hooks become fastened to silken threads that have been spun by the larva on the leaf, so that the pupa is held securely, even if the greater part of the body is extended. While the writer was examining rearing cages on July 3 (8 a. m.), a pupa was noticed wriggling out of its pupation quarters.

The following observations were made:

8.20 a. m. The pupal skin or shell was cracked in the anterior region.

8.25 a. m. Moth about half out.

8.30 a. m. Moth left the pupal shell, the body being still wet and the wings quite wrinkled.

8.35 a. m. Body dry and wings straightened out and folded over back.

8.43 a. m. Wings have separated and are held roof-like over the back.

8.55 a. m. Moth crawling about in glass jar quite actively.

8.58 a. m. Observations ceased; moth was fluttering about the cage.

Total time consumed in emergence, approximately 10 minutes.

It will be noted that the time required for this moth to emerge after the breaking of the pupal skin was about 10 minutes, and inside of five minutes after emergence its body and wings were dry, but the moth did not become active until about 20 minutes had elapsed.

THE ADULT AND EGG STAGES.

From material under observation the first moth emerged on June 7 and the latest ones appeared on June 24. The maximum emergence of moths was on June 14 and 15. In the field the period during which the greatest number of moths appeared was from about June 22 to July 1. The first moth was noticed in the orchard on June 9, and by July 20 practically all moths had disappeared. From about June 25 to July 10 most egg masses were being deposited on the trees. The following egg-laying records were obtained in rearing cages, and these have a direct bearing on the length of life of the moths.

On June 21 at 8 a. m. a male and female that had emerged during the previous night were placed in a jar in which was put a small twig, so that there would be a suitable place for oviposition. The cage was examined on June 22 and both moths were quite active. On June 23 at 5 p. m. the male moth was found dead in the bottom of the jar, but the female was actively crawling about in the cage. At 8 a. m. the next day (June 24) a medium-sized egg mass was deposited on the twig. The moths were not observed copulating. The eggs

had been laid some time during the interval between 5 p. m. on June 23 and 8 a. m. on June 24. The female was dead on June 25 (8 a. m.). The female lived for about four days and the male only about two days. Eggs were deposited in two and one-half days.

On July 1 (8 a. m.) a male moth and a female moth just emerged were placed in a jar with an apple twig. Food was furnished the pair of moths by supplying them with a piece of absorbent cotton which had been saturated in a weak solution of sirup. The cage was examined the next day at 9 o'clock and both moths were quite restless. On July 3 at 8 a. m. an egg mass was found on the twig and both moths were still active. The male had died by 9 a. m. on July 4 and the female by 8 a. m. on July 5. Copulation was not observed. In this case the male lived about three days and the female about four days. The eggs were laid inside of two days after emergence of the moths.

On July 16 two moths were observed mating and at noon were put in breeding jar. The cage was again examined on July 17 and the moths had ceased copulating and were crawling over the sides of the jar. On July 18 at 4 p. m. the cage was again looked over and an egg mass was found deposited on the twig. The life of the moths could not be determined, as the time of emergence was not known. A period of about two days is shown between the time of copulation and the time of deposition of the egg mass.

There are not sufficient data bearing on the length of life of the adults to justify any generalization. The writer believes there is a wide variation in the longevity of the moths and that the females usually outlive the males. It is also reasonable to expect the moths to live for a longer period under natural conditions than is the case when they are kept in confinement. It is also likely that the females do not oviposit out of doors as readily as when confined in rearing jars with the males.

Observations under insectary conditions go to prove that the female if left unmolested during oviposition deposits all her eggs in a single mass. All egg masses deposited in rearing cages consisted of more than 100 eggs, the greatest number from one female being 140. In the orchard it is not difficult to find rather small egg masses. The smallest one observed was composed of 25 eggs. In making field observations the writer noticed that the female when ovipositing would cease the operation very readily if disturbed in any way and fly or crawl away. Ovipositing females were observed changing position when insects such as ants, ground beetles, and ladybird larvæ or adults came too near them. One species of Coccinellidæ that is especially predaceous on the green aphid of the apple was noticed several times disturbing females in the act of oviposition, compelling them to crawl or fly to another place to deposit the

remainder of their eggs. This restless habit of the females may account for the many small egg masses that are found in the orchard. The eggs are usually laid at night. Moths have, however, been seen laying eggs as early in the evening as 5.30.

SUMMARY OF LIFE HISTORY.

The larval stage in the material under observation varied from 24 to 35 days, the average being 28.05 days; the pupal stage from 9 to 15 days, the average being 11.25 days; and the adult or moth stage from 2 to 3 days for the males and 3 to 4 days for the females. The life of the moths is probably longer than this under normal conditions. Females were depositing eggs between 2 and 3 days after emergence. In the field (under Colorado conditions) the period of egg laying extended from about the second week in June to the middle of July, the maximum being reached from June 25 to July 10. The eggs remain on the trees unhatched until the following spring. Hence this insect has only one generation in the course of a year. The hatching of the eggs in the spring may extend over a period of many days, depending on the weather. The time of hatching of the eggs will vary greatly with the different seasons and in different sections of the country. Generally speaking, it may be stated that the eggs will begin hatching about the time the cluster buds of early-blooming varieties of apples are beginning to show, but before they have fully separated.

HIBERNATION.

The fruit-tree leaf-roller passes the winter in the egg stage. The eggs are deposited in masses on various parts of the host plants by females during June or July. The trunks and larger limbs or branches are often just "peppered" with them. A goodly number are also to be found on the smaller branches, twigs, and fruit spurs. Egg masses are, however, not only laid on fruit trees, but on various other plants. The writer has observed them on elm, soft maple, box-elder, currant, gooseberry, raspberry, grape, rose, lilac, and Virginia creeper. Besides the above plants, the masses have been noticed on spray tanks, on sides of buildings, and on fences. On account of the indiscriminate deposition of its eggs this insect will be found to be more difficult of control.

Observations have shown that the eggs begin hatching quite early in the spring just as the cluster buds on early blooming varieties of apples are exposed. About the time that practically all the cluster buds have fully separated nearly one-half of the eggs have hatched. On late-blooming varieties of apples, such as Rome Beauty, Jeniton, etc., the date of appearance of the larvæ is the same, although the buds are not nearly so far advanced. On Rome Beauty and Jeniton

trees it was found to be a much harder problem to do as effective spraying with arsenicals as on Jonathan, Ben Davis, Maiden Blush, and other varieties that developed their buds early. If the fruit and leaf buds are not much advanced it is very difficult to get the spray mixture where the larvæ are actually feeding. The period of hatching of the eggs may be quite prolonged, depending on climatic conditions. During the season of 1912, in the orchards, the eggs were hatching from April 20 to May 9, making a period of 19 days. It should, however, be noted that weather conditions were exceptionally cool after a short warm spell during which the eggs began to hatch. Under more favorable conditions all eggs would probably hatch inside of a week or ten days. On account of the long hatching period spraying against the larvæ was found to be very difficult.

NATURAL ENEMIES.

Several species of birds have been observed feeding upon the larvæ of the fruit-tree leaf-roller. The list is as follows: The bluebird (*Sialia sialis*), western robin (*Planesticus migratorius propinquus*), catbird (*Dumetella carolinensis*), red-winged blackbird (*Agelaius phœniceus phœniceus*), orchard oriole (*Icterus spurius*), kingbird (*Tyrannus tyrannus*), phœbe (*Sayornis phæbe*) and English sparrow (*Passer domesticus*).

The writer has reared a number of parasitic insects from the larvæ and pupæ of the leaf-roller, as follows: *Pimpla pedalis* (Cress.), *Itopectis conquisitor* (Say), *Epiurus indigator* (Walsh), and *Meteorus archipsidis* Vier.; the latter is the same species as that reared from this host by Mr. R. W. Braucher at Bethany Center, N. Y. The following Diptera also were reared from this host: *Exorista nigripalpis* Towns., *E. pysts* Walk., *E. blanda* O. S., and *E. chelonix* Rond.

A few insects were found to be predaceous upon the fruit-tree leaf-roller. *Calosoma scrutator* was taken feeding on the larvæ and *Notoxus monodon* Fabr. was collected at two different times feeding on the pupæ in rolled-up leaves. *Formica montanus* Emery has also been seen attacking the larvæ and pupæ.

A small mite, which Mr. Nathan Banks considers to be a new species of *Erythræus*, was found feeding upon the eggs of the leaf-roller. The mites belonging to this genus are said to be always predaceous, and some of them feed on scale insects.

METHODS OF CONTROL.

During the winter of 1911-12 and the spring of 1912 many experiments were made at Espanola, N. Mex., and Canon City, Colo., against the fruit-tree leaf-roller. The experimental work will be taken up separately according to the locality in which it was conducted.

EXPERIMENTAL TESTS FOR THE DESTRUCTION OF THE EGGS.

Many laboratory tests were made for the destruction of the eggs. Only egg masses deposited on twigs were used, and these twigs were dipped in the various mixtures employed. After treatment the masses were kept in separate jars. The results of the test are shown in Table III.

TABLE III.—*Tests of sprays for the destruction of eggs of the fruit-tree leaf-roller.*

No. of experiment.	Material used.	Date of application, 1912.	Number of egg masses treated.	Number of egg masses unhatched.	Number of egg masses hatched.	Remarks.
1	Miscible oil (1:12).....	Jan. 3	10	10	0	
2	Miscible oil (1:15).....	do.	10	10	0	
3	Miscible oil (1:20).....	do.	10	10	0	
4	Miscible oil (1:10).....	do.	5	5	0	
5	25 per cent kerosene emulsion.	do.	10	9	1	3 eggs in mass hatched.
6	20 per cent kerosene emulsion.	do.	10	10	0	
7	25 per cent crude petroleum emulsion.	do.	5	5	0	
8	20 per cent crude petroleum emulsion.	do.	5	4	1	12 eggs in mass hatched.
9	8 per cent distillate-oil emulsion.	do.	5	5	0	
10	5 per cent distillate-oil emulsion.	do.	5	0	5	Most all the eggs hatched.
11	Commercial lime-sulphur (1:8).	do.	10	0	10	Practically all eggs hatched.
12	Commercial lime-sulphur (1:9).	do.	5	0	5	Do.
13	Commercial lime-sulphur (1:10).	do.	5	0	5	Do.
14	Commercial lime-sulphur (1:11).	do.	5	0	5	Do.
15	Commercial lime-sulphur (1:12).	do.	5	0	5	Do.
16	Check—untreated (caged).	do.	5	0	5	All egg masses hatched well.
17	Miscible oil (1:12).....	Mar. 5	15	15	0	
18	Miscible oil (1:15).....	do.	15	14	1	Only 1 egg hatched.
19	Miscible oil (1:18).....	do.	15	15	0	
20	25 per cent kerosene emulsion.	do.	10	10	0	
21	20 per cent kerosene emulsion.	do.	10	9	1	6 eggs in mass hatched.
22	25 per cent crude petroleum emulsion.	do.	9	7	2	7 eggs in 2 masses hatched.
23	10 per cent distillate-oil emulsion.	do.	10	10	0	
24	Check—untreated (caged).	do.	10	0	10	All eggs hatched well.
25	Miscible oil (1:12).....	Apr. 14	86	84	2	1 egg in each mass hatched.
26	Miscible oil (1:15).....	do.	122	119	3	7 eggs in 1 mass hatched; about one-fourth total eggs in 2 masses hatched.
27	Whitewash.....	do.	25	0	25	Practically all eggs hatched.
28	Check—untreated (caged).	do.	113	0	113	107 masses hatched well; about one-half total eggs hatched in 6 masses.

It will be noted that the miscible oil ranging in strength from 1:10 to 1:20 gave the best results. The crude-petroleum kerosene and 10 per cent distillate-oil emulsions ranked second in effectiveness. Commercial lime-sulphur solution was found to be ineffective, as was whitewash.

SPRAYING EXPERIMENTS FOR THE DESTRUCTION OF THE EGG MASSES.

EXPERIMENTS AT ESPANOLA, N. MEX.

The work at Espanola, N. Mex., was conducted in the apple orchard of Mr. Henry L. Pollard. The orchard consisted of 14-year-old trees in fair condition. For the spraying a barrel outfit was used and the pressure maintained ranged from about 75 to 100 pounds. The number of trees in each of the plats is shown as follows: Plat I, 21; Plat II, 22; Plat III, 14; Plat IV, 22; Plat V, 22; Plat VI, 6. The days upon which the sprays were applied were clear and quite cool. The results of the experiments are shown in the following table:

TABLE IV.—*Spraying experiments for destruction of egg masses of the fruit-tree leaf-roller, Espanola, N. Mex., 1911-12.*

Plat No.	Treatment.	Number of count trees.	Total number of egg masses observed.	Number of egg masses hatched.	Number of egg masses unhatched.	Percentage of egg masses—	
						Hatched.	Unhatched.
I	Commercial lime-sulphur solution at 1 gallon to 8 gallons water on December 14, 1911.....	6	265	263	2	99.24	0.76
II	Commercial lime-sulphur solution at 1 gallon to 10 gallons water on December 14, 1911.....	6	277	276	1	99.63	.37
III	Miscible oil at 1 gallon to 15 gallons water on December 14, 1911.....	6	310	21	289	6.77	93.23
IV	Commercial lime-sulphur solution at 1 gallon to 9 gallons water on February 17, 1912.....	6	285	285	0	100.00	0
V	Commercial lime-sulphur solution at 1 gallon to 7 gallons water on February 17, 1912.....	6	252	251	1	99.60	.40
VI	Miscible oil at 1 gallon to 12 gallons water on February 17, 1912.....	6	272	16	256	5.88	94.12
VII	Unsprayed.....	6	250	250	0	100.00	0

As will be noted, the trees sprayed with miscible oil showed good results from the spraying. The spraying of Plat III with the oil at the rate of 1 gallon to 15 gallons of water prevented 93.23 per cent of the eggs from hatching, and Plat VI, upon which the oil was used at the rate of 1 gallon to 12 gallons of water, showed a benefit of 94.12 per cent in favor of the spraying as compared with the checks. It should also be noted that all egg masses on the unsprayed trees hatched. The commercial lime-sulphur solutions gave little or no beneficial results for the treatment. On Plat IV practically all the eggs hatched, and on Plats I, II, and V there was only a benefit of 0.76, 0.37, and 0.40 per cent, respectively, from the treatment as compared with the check trees, upon which all the eggs hatched.

EXPERIMENTS AT CANON CITY, COLO.

The work at Canon City, Colo., was conducted in the orchards of Mr. E. A. Davis and Dr. Allen Bell. In the Davis orchard 14-year-old Ben Davis trees were sprayed, and in the Bell orchard the varieties treated consisted of Ben Davis, Winesap, and Colorado Orange. The trees in the Bell orchard were sprayed with miscible oil at the strengths of 1 gallon to 12 gallons of water and 1 gallon to 15 gallons of water and with 20 per cent kerosene emulsion, but unfortunately the material was not at all thoroughly applied, and no conclusions as to the efficiency of the sprays can be drawn from the results obtained. Duties elsewhere required the absence of the writer from Canon City when the applications were made. The trees in the Davis orchard, on the other hand, were thoroughly sprayed with a gasoline-power sprayer. The pressure maintained ranged from 150 to 175 pounds. At the time of the application the buds were just bursting and beginning to show the green. The results are shown in Table V.

TABLE V.—*Spraying experiments for destruction of egg masses of the fruit-tree leaf-roller, Canon City, Colo., 1912.*

Plat No.	Treatment.	Count tree No.	Total number of egg masses observed.	Number of egg masses—		Percentage of egg masses—	
				Hatched.	Un-hatched.	Hatched.	Un-hatched.
I	Miscible oil at 1 gallon to 15 gallons of water on April 16, 1912.	1	184	5	179	.....	.....
		2	128	4	124	.....	.....
		3	116	4	112	.....	.....
		4	135	6	129	.....	.....
		5	176	8	168	.....	.....
		6	110	6	104	.....	.....
			849	33	816	3.88	96.12
II	Check, unsprayed	1	155	155	0	.....	.....
		2	185	184	1	.....	.....
		3	178	178	0	.....	.....
			518	517	1	99.80	0.20

It will be noted that a comparison as to the number of egg masses that failed to hatch between the trees on Plat I, sprayed with miscible oil at the rate of 1 gallon to 15 gallons of water, and Plat II, which was left untreated, shows a benefit of 95.92 per cent in favor of the spraying.

At Canon City, Colo., no experiments were performed with lime-sulphur. The writer had, however, an opportunity to examine several orchards in this section that were sprayed with this material against the Howard scale (*Aspidiotus howardi* Ckll.). The lime-sulphur was found to be entirely ineffective in destroying the eggs of the leaf-roller.

SPRAYING EXPERIMENTS AGAINST THE LARVÆ.

The experiments against the larvæ were conducted in the Davis orchard at Canon City, Colo. This orchard consisted of many varieties, namely, Ben Davis, Missouri Pippin, Winesap, Paragon, Jeniton, Rome Beauty, Jonathan, Maiden Blush, Yellow Transparent, and Red Astrakhan. There were also a few trees of other varieties. The orchard as a whole had no more than a good one-fifth crop. On account of the light crop it was difficult to determine fairly the results of the spraying on some plats. In all cases the material was applied with a good gasoline-power outfit and a pressure ranging from 150 to 200 pounds was maintained. The plats contained trees as follows: I, 155; II, 72; III, 31; IV, 63; V, 46; VI, 38; VII, 26; VIII, 30; IX, 41; X, 6.

The results are shown in Table VI.

TABLE VI.—*Spraying experiments against the larvæ of the fruit-tree leaf-roller, Canon City, Colo., 1912.*

Plat No.	Treatment.	Percentage of injured apples.	Percentage of sound apples.	Condition of foliage.
I	Two applications of arsenate of lead, 3 pounds to 50 gallons of water, May 2 and May 17 and 18.	20.00	80.00	Good; no arsenical injury.
II	Two applications of arsenate of lead, 3 pounds to 50 gallons of water, plus 4 ounces Paris green.	20.00	80.00	Do.
III	Two applications of arsenate of lead, 3 pounds to 50 gallons water, plus 40 per cent nicotine solution (1:1,000), May 3 and 25.	15.00	85.00	Very good; no arsenical injury.
IV	One application of arsenate of lead, 3 pounds to 50 gallons water, plus 40 per cent nicotine solution (1:1,000), May 3.	15.00	85.00	Do.
V	Two applications of arsenate of zinc, 1 pound to 50 gallons water, May 11 and 25.	25.00	75.00	Fair; serious arsenical injury.
VI	One application of Paris green, 8 ounces to 50 gallons water, plus 2 pounds lime, May 4; one application of Paris green, 1 pound to 50 gallons water, plus 2 pounds lime, May 18.	18.00	82.00	Good; slightly burned by arsenical.
VII	One application of 40 per cent nicotine solution at 1:800, plus 2 pounds of soap, May 11.	No crop.	No crop.	Fairly good.
VIII	One application of 40 per cent nicotine solution at 1:800, plus 2 pounds of soap, May 18.	35.00	65.00	Fair.
IX	One application of 40 per cent nicotine solution at 1:1,000, plus 2 pounds of soap, May 18.	40.00	60.00	Do.
X	Check; unsprayed.....	98.00	2.00	Trees nearly defoliated.

NOTE.—Plats I, IV, VII, VIII, and IX were sprayed with arsenate of lead at the rate of 3 pounds to 50 gallons of water for the codling moth when the petals had dropped. Plats II and VI received the same treatment for the leaf-roller as for the first codling-moth application.

The damage to fruit was determined by making careful counts of fruits from various trees in the different plats. The total number of fruits was not counted in any case, so the percentages given are only approximate. On Plat VII there was a total crop failure.

As will be noted, the best results were obtained on Plats III and IV, where a combination of arsenate of lead (3:50) and 40 per cent nicotine solution was used. The 40 per cent nicotine solution was found to be effective only when the larvæ were quite small. It was

estimated that the tobacco mixture applied May 2 and 3 destroyed about 50 per cent of the worms then on the trees. Plat III, which received two applications of the combination spray, showed no better results than on Plat IV, which received only arsenate of lead for the second treatment. Plat VI (Paris green alone) showed a slight improvement over Plats I (arsenate of lead 3:50) and II (arsenate of lead 3:50 plus 4 ounces Paris green). Plat V, which was sprayed with arsenate of zinc at the rate of 1 pound to 50 gallons of water, gave disappointing results, as it not only failed to destroy the larvæ in goodly numbers but it seriously burned the foliage. The arsenical injury to the foliage could, however, have been prevented if lime had been added. An increased strength of this arsenical would no doubt have been more effective. On Plats VII, VIII, and IX, where 40 per cent nicotine solution alone was used, the benefit from spraying was considerably less. Plat VII of these plats gave the best results. On the day after the spraying, by carefully counting the number of dead larvæ as compared with the living ones found on the trees, it was found that about 55 per cent of the larvæ were killed by the spray. On Plats VIII and IX not more than 25 per cent of the larvæ were killed. These plats, however, were sprayed a week later than Plat VII, and the difference in results was probably due to the fact that the worms at that time were more resistant to the tobacco mixture and that it was much more difficult to reach them in the rolled-up leaves.

It will be noted in comparing the sprayed plats with the unsprayed plat as to the amount of injury to the fruit alone that there is much in favor of spraying. The benefit for each plat over the check plat is shown in percentages as follows: Plat I, 78; Plat II, 78; Plat III, 83; Plat IV, 83; Plat V, 73; Plat VI, 80; Plat VII, 73; Plat VIII, 83; Plat IX, 83. The difference in condition of foliage must not be lost sight of in determining the benefit of spraying. The check trees were practically defoliated, while the sprayed trees retained their foliage throughout the season and were enabled to develop fruit buds for the following season.

Although there is much in favor of spraying with arsenicals, alone or in combination with tobacco, they have not given entire satisfaction.

LIGHT TRAPS.

The writer had occasion to observe many lights used as traps to catch the moths of the leaf-roller at Canon City, Colo., during the season of 1912. The use of these traps was not advocated, but many orchardists were of the opinion that a decided benefit would be derived if enough lights were placed in the orchard, as the moths were very readily attracted to them. Such orchards were examined

very carefully on several occasions to see if there was any appreciable difference in the number of eggs being deposited in them and in adjacent orchards where lights were not employed. It must be stated emphatically that these traps caught vast numbers of the moths, but so far as could be determined there was little difference in the number of egg masses laid on the trees in these orchards than elsewhere in the same immediate region. Some growers, before the moths ceased flying, gave up the use of the light traps after they were convinced that there was little hope of receiving much benefit in that way. Light traps have never proven a success in controlling an injurious insect. Although some benefit may be derived, it is so slight that other means must be adopted in fighting the pest.

Orchardists have told the writer of their endeavors to get rid of the leaf-roller by crushing all egg masses that could be found on the trees. Cases are known where growers have actually hired men to go over their trees during the winter for the purpose of destroying the eggs, thinking that it was possible to control the pest by such operations. In the spring they found, much to their surprise, that the steps taken during the winter season were of little use, as the "worms" appeared, as usual, in enormous numbers on all trees. Under orchard conditions it should be distinctly understood that there is no hope of practically controlling the leaf-roller by destroying the egg masses by hand, because the masses are deposited on all parts of the trees and their small size and close resemblance to the color of the bark make their discovery difficult.

CONCLUSIONS.

The fruit-tree leaf-roller in the larval stage has been found difficult of control because of the manner in which the larvæ feed on the foliage and fruit, and also on account of the fact that they are very resistant to poison sprays. Applications of arsenicals alone and in combination with 40 per cent nicotine solution have greatly reduced the amount of injury to the fruit and foliage, but these sprays have not been so effective as is desirable.

A series of experiments for the destruction of the egg masses, conducted during the dormant season, have shown the value of mineral oils. Kerosene emulsion, crude-petroleum emulsion, and miscible oils have been tested. The last mentioned, when used at the strength commonly employed against the San Jose scale—that is, 1 gallon to 15 gallons of water—will prevent most of the eggs from hatching. From 93.23 to 96.21 per cent of the egg masses were destroyed by this material on the experimental plats. Good results also were obtained by the use of kerosene and crude-petroleum emulsions, although these substances were, on the whole, not quite equal to the

miscible oils. The ease with which sprays may be prepared from these last commend them to many orchardists although the homemade emulsions are cheaper. In preparing a kerosene or crude-petroleum emulsion care is necessary to insure a thorough and stable emulsion.

It should be stated that injury to trees treated with oils sometimes follows, although no such injury was noted in connection with the present experiments. No more spray should be used than is necessary properly to treat the tree, and the puddling of oil around the crown should be guarded against.

Lime-sulphur solutions proved to be a decided failure as a destroyer of the egg masses. Strengths ranging from 1 gallon of lime-sulphur to 7 gallons of water to 1 gallon of lime-sulphur to 10 gallons of water were sprayed on apple trees and no benefit was derived from their use.

RECOMMENDATIONS FOR CONTROL.

Experimental work has shown that the best method for controlling the fruit-tree leaf-roller is by a very thorough application of a miscible oil at the rate of 1 gallon to 15 gallons of water during the dormant season. It must be understood that by thoroughness of application is meant the use of enough material to cover all parts of the tree, from the tip of the highest or smallest branch to the very base of the trunk. In order to do thorough work the trees must necessarily be sprayed from all directions. It is very often the case that the top branches or those around the inside are missed by the man operating the rod. It must be remembered that only those egg masses actually hit or covered with the material will fail to hatch and those missed will surely hatch out "worms" in the spring to feed upon the trees. Orchardists should realize that thorough spraying with the right material and at the proper time pays well, but careless, haphazard work gives disappointing returns.

All plants upon which eggs have been laid should be sprayed. Besides fruit trees, egg masses may be found on various shade trees, shrubs, and currant, gooseberry, raspberry, and rose bushes, etc. Eggs will also be found on buildings, spray outfits, wagons, fences, etc., and it is recommended that these egg masses be crushed so far as is practicable.

The best time to spray is just before the buds burst in the spring. Late spring is preferable to early spring, as weather conditions are usually more favorable. There is also less likelihood of injury to the trees by the oil after the sap has begun to flow with considerable pressure. Spraying should not be done during threatening weather. Orchardists should bear in mind that the strength of miscible oil recommended is for a dormant spray and should never be applied to trees in foliage. Spraying should be completed in the spring before

the buds have advanced so far as to have the green tips exposed. If the above precautions are carefully followed in applying the miscible oil, danger of injury to trees will be reduced to the minimum.

There are a number of good commercial brands of miscible oil on the market. These miscible or soluble oils are so made that they mix readily with water. The material may be applied either by hand pump or gasoline-power sprayers. Power outfits are to be preferred. Nevertheless, whichever kind of outfit is employed, it is essential that it be provided with a good working agitator. To do effective work it is also necessary to have sufficiently long spray rods and leads of hose. Nozzles with medium-sized holes or apertures are recommended.

Miscible oils at the strength recommended for the destruction of the eggs of the fruit-tree leaf-roller are valuable in controlling scale insects such as the San Jose scale (*Aspidiotus perniciosus* Comst.), Howard scale (*Aspidiotus howardi* Ckll.), etc. Orchards sprayed with the oil for the leaf-rollers will not require the usual application of lime-sulphur for the San Jose or Howard scales.

In conjunction with the oil treatment in badly infested districts it is recommended that a very thorough application of arsenate of lead, at the rate of 3 pounds to 50 gallons of water, be applied when the larvæ are emerging from the eggs. The larvæ will be found to be hatching just as the cluster buds on early-blooming varieties of apple are beginning to separate. The necessity for making this application will depend largely upon the thoroughness with which the miscible oil was applied.

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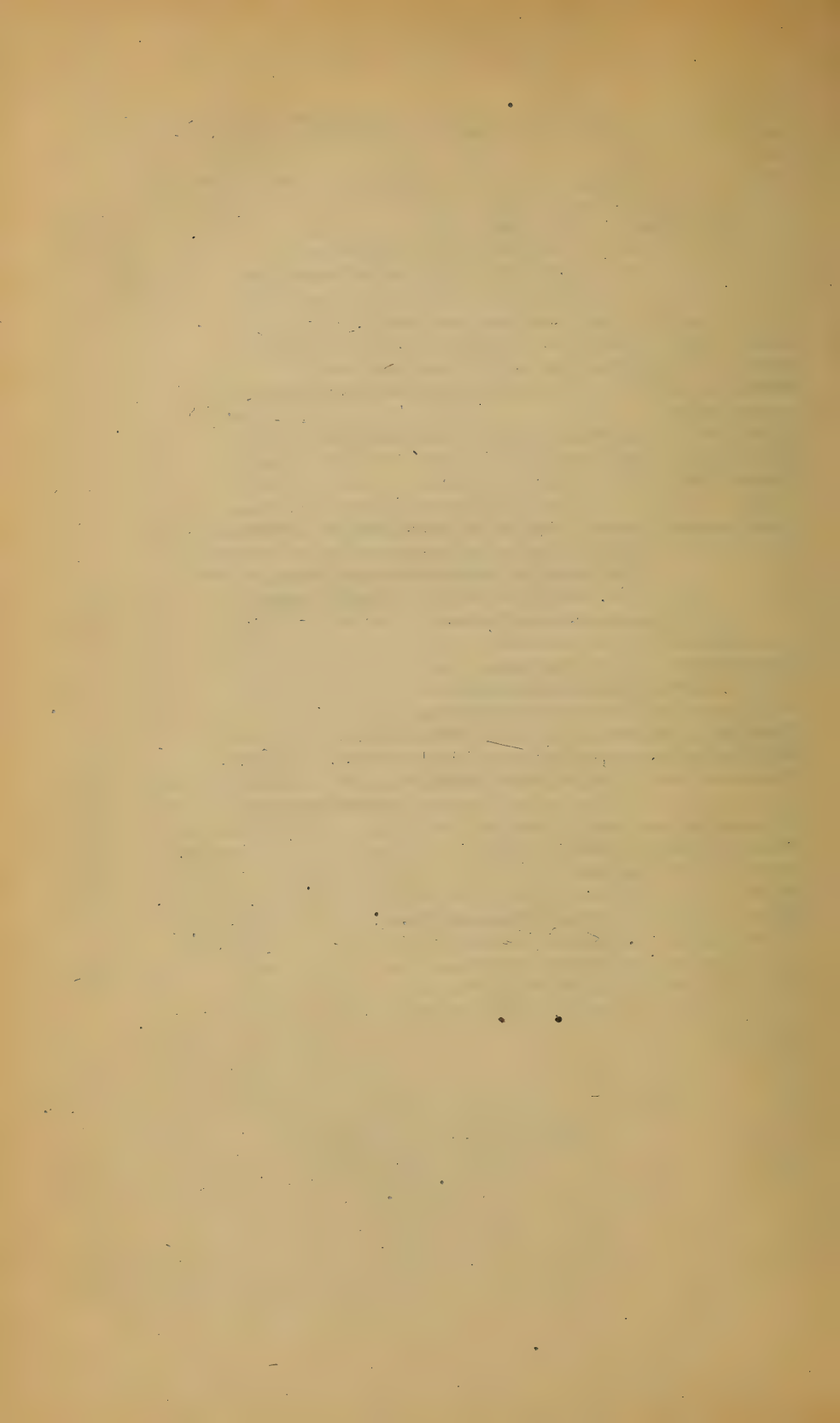
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L. O. HOWARD, Entomologist and Chief of Bureau.

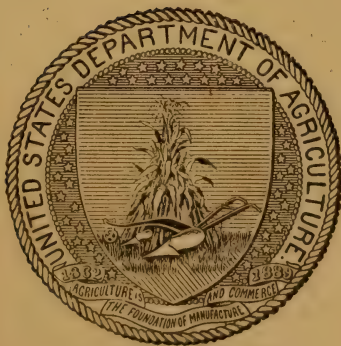
THE RED SPIDER ON HOPS
IN THE SACRAMENTO VALLEY
OF CALIFORNIA.

BY

WILLIAM B. PARKER, M. S.,

Entomological Assistant.

ISSUED MAY 3, 1913.



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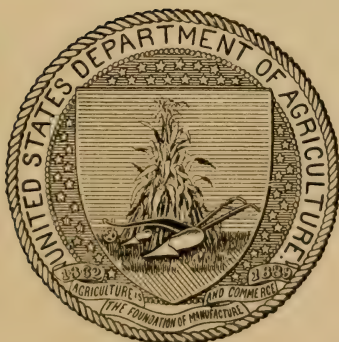
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LETTER OF TRANSMITTAL.

U. S. DEPARTMENT OF AGRICULTURE,
BUREAU OF ENTOMOLOGY,
Washington, D. C., November 15, 1912.

SIR: I have the honor to transmit herewith, and to recommend for publication as Bulletin No. 117 of the Bureau of Entomology, a manuscript entitled "The Red Spider on Hops in the Sacramento Valley of California," by William B. Parker, an entomological assistant in this bureau.

This manuscript deals with a pest the study of which has been hitherto largely neglected and which of recent years has attracted much attention from an economic standpoint, on account of immense losses to growers of hops and other crops in the Pacific coast region and elsewhere.

Mr. Parker's studies, as outlined in this paper, have added considerably to the knowledge of the habits of this pest and have shown methods by which it may be economically controlled.

Respectfully,

L. O. HOWARD,
Entomologist and Chief of Bureau.

Hon. JAMES WILSON,
Secretary of Agriculture.

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THE RED SPIDER ON HOPS IN THE SACRAMENTO VALLEY OF CALIFORNIA.

INTRODUCTION.

The common "red spider" (*Tetranychus bimaculatus* Harvey) has long been known as a pest in flower gardens and greenhouses, where it is often very injurious on ornamental plants. This damage, however, becomes quite insignificant when the injury to hopvines is considered. During the past few years this mite has become recognized as one of the most injurious of hop pests on the Pacific coast and especially so in the Sacramento Valley of California.

The investigation upon which this bulletin is based was begun January 1, 1911, at the request of the horticultural commission of Sacramento County and in cooperation with the E. Clemens Horst Hop Co., of San Francisco, and extended over a period of 18 months. Observations were made throughout this period in the hop fields in all parts of the Sacramento Valley, and spraying experiments were conducted on both a large and a small scale.

The recorded efficiency of the various insecticides tested during this investigation is based upon actual counts of mites present before and after spraying, as well as upon general observations under ordinary field conditions.

ECONOMIC IMPORTANCE.

The red spider was reported in injurious numbers in the hop fields at Wheatland, Yuba County, Cal., in 1902. Since then it has done some injury to hops in the Sacramento Valley every year and in 1910 the hop crop was seriously injured in many localities. One company, the E. Clemens Horst Co., estimated their financial loss due to this mite in a few of their hopyards near Sacramento, Cal. (allowing 14 cents per pound for hops), to be from \$10 to \$68 per acre. Other growers were not able to pick their hops so rapidly as did this company, and their loss was necessarily much greater. In some yards near Sacramento the hops were so badly injured that they could not be picked at all and were allowed to remain in the field.

NOTE.—Obligations are due to the manager of the E. Clemens Horst Co. and to the superintendent of the ranches at Perkins and at Wheatland, who placed at my disposal every means possible to carry on the work; to Prof. W. B. Herms, for many valuable suggestions; to Mr. E. K. Carnes, superintendent of the State insectary, Sacramento, Cal., who generously provided me with desk room; and to Dr. F. H. Chittenden, under whose directions the investigation was carried on.—W. B. P.

An extract from a letter from a former hop grower in Washington State describes conditions there as follows: "The 'red spider' was here in 1901, but did little damage. It gradually increased until 1905, when we let 25 of 85 acres blow away and what we did bale was trash. Then we gave up the fight."

The red spider is reported to have been very destructive to hops at Agassiz, British Columbia, but for the past few years has not appeared in injurious numbers.

The past seasons were very late, and the mites were not present in noticeable numbers in the hop fields near Sacramento until the middle of June. Even so, they had done much damage by August, 1911, and if the crop had not been promptly and rapidly picked many of the hops would have "blown away," resulting in the total loss of a great portion of the crop.

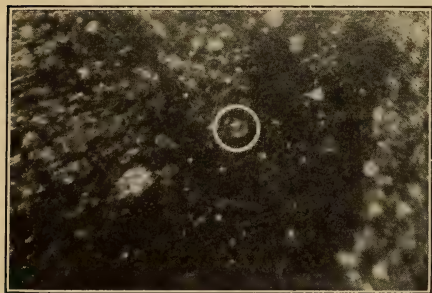


FIG. 1.—The red spider (*Tetranychus bimaculatus*): Egg (position indicated by white circle) among webs on surface of leaves. Greatly enlarged. (Original.)

LIFE HISTORY.

THE EGG.

Description.—The eggs of *Tetranychus bimaculatus* (fig. 1) are small, spherical, pearl-like objects, about one-sixth of a millimeter in diameter, though somewhat variable in size.

From 10 to 450 are usually present on a leaf, and with the aid of a hand lens they are readily found upon infested foliage.

Where laid.—The eggs are deposited singly and are promiscuously distributed among the webs and upon the underside of the leaves. They are not attached to the host plant by protecting webs, as are the eggs of the citrus "red spider" (*Tetranychus mytilaspidis* Riley), but are held by strong filaments with which they chance to come in contact. Many eggs have been observed on the loose web which is ordinarily spun over infested leaves.

Incubation.—The incubation period varies according to temperature and general climatic conditions. In the experiments conducted at Berkeley, Cal., during February, 1912, the incubation period was found to be from 8 to 10 days. This period during May was from 5 to 10 days, with an average of 7.2 days, while in July, 1911, and during some very warm weather in 1912 it was only $4\frac{1}{2}$ days. The relatively higher temperatures of the summer are responsible for this shortening.

THE LARVA AND NYMPH.

Descriptive.—The larva (fig. 2) is a minute, almost globular object, and differs from the adult in the possession of only three pairs of legs. This six-legged condition lasts only during the first stage, i. e., until the first molt, from which the mites emerge as nymphs, with four pairs of legs, and, except for size and the maturity of the sexual organs, similar to the adults. According to C. H. Perkins,¹ the sexual organs appear with the second molt, but copulation does not take place until after the third.

Length of stages.—The length of the larval and nymphal periods varies, being from 8 to 16 days, according to the prevailing temperature. As shown in Table I, this period under the temperature conditions given in the plat was 15 to 16 days. During May, however, this period was found to be 11 to 12 days and in July, 1911, which was an exceptionally warm month, two mites were observed to be mature 8 days after emerging from the egg.

Under field conditions in 1911 it was impossible to carry out any very extensive life-history experiments. During the winter, however, a series was carried out in the insectary of the University of California, at Berkeley, Cal.

This series is recorded in Table I.

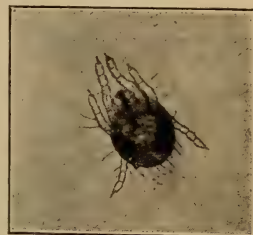


FIG. 2.—Larva of the red spider. The legs in this stage are transparent. Greatly enlarged. (Original.)

TABLE I.—Transformations and length of stages of the red spider in California, 1912.

No.	Eggs laid.		Hatched.		Length of stage.	First molt.		Length of stage.
	Date.	Time.	Date.	Time.		Date.	Time.	
					Days.			Days.
1.....	Feb. 6	9 a. m....	Feb. 16	8 a. m....	10	Feb. 20	5 p. m..	4½
2.....	6	9 a. m....	15	12 m....	9	20	9 a. m..	5
3.....	6	1 p. m....	16	3 p. m....	10	20	4 p. m..	4
4.....	6	3.30 p. m..	16	11 a. m....	10	20	4 p. m..	4½
5.....	7	8 a. m....	16	3 p. m....	9	20	9 a. m..	3½
6.....	8	3 p. m....	16	3 p. m....	8	20	9 a. m..	13½
7.....	7	9 a. m....	16	3 p. m....	9	21	4 p. m..	5

No.	Second molt.		Length of stage.	Third molt.		Length of stage.	First egg laid.		Total time, egg to adult.
	Date.	Time.		Date.	Time.		Date.	Time.	
			Days.			Days.			Days.
1.....	Feb. 25	4 p. m...	5	Feb. 29	9 a. m....	3½	Mar. 2	11 a. m..	25
2.....	25	4 p. m...	5½	29	9 a. m....	5½	2	11 a. m..	25
3.....	25	4 p. m...	5	29	9 a. m....	3½			
4.....	25	4 p. m...	5	29	9 a. m....	3	2	11 a. m..	25
5.....	25	4 p. m...	5½				2	11 a. m..	24
6.....	25	9 a. m...	5	29	9 a. m....	4	2	11 a. m..	23
7.....	25	4 p. m...	4	Mar. 1	11 a. m....	4½	3	11 a. m..	25

¹ Report of the Vermont Agricultural Experiment Station, 1896-97.

THE ADULT.

Description.—The adults of *Tetranychus bimaculatus* (figs. 3, 4) are small, greenish yellow or, in some cases, reddish mites ranging in size from 0.27 mm. in the male to 0.50 mm. in the female. The abdomen joins the cephalothorax, formed by the fusion of the head and thorax, at its full width and extends over the portion to which the posterior pair of legs is attached. The abdomen, the cephalothorax, and particularly the appendages are well provided with hairs.

The two sexes are very distinct. The female is much the larger and has a broad, rounded abdomen, while in the male the abdomen is narrow and tapering. These differences are so well marked that the sexes may be distinguished under an ordinary hand lens.



FIG. 3.—The red spider: Adult female, dorsal view. Greatly enlarged. (Original.)

Copulation.—Copulation begins as soon as the mites become adult, the female often receiving several males. Contrary to the usual method, however, the male operates from beneath the female. The male mite forces its way under the abdomen of the female, braces its legs against the leaf, and directs the genitalia over its back.

Parthenogenesis.—The idea that parthenogenesis occurs with the red spider is an old one, and during this investigation a few experiments were carried on along this line. A morning-glory (*Ipomœa* sp.) was cleaned of all mites and eggs, the petioles of the leaves were banded with tree tanglefoot, and adult mites were placed upon 10 of the leaves. After eggs were observed the female and all but one of the eggs were



FIG. 4.—The red spider: Adult male, dorsal view. Greatly enlarged. (Original.)

carefully removed from each leaf. When mature the two females that survived upon the isolated leaves were carefully watched to be sure that no male mite reached them. Thirty-three eggs were deposited by these virgin mites and all of the 26 that hatched were males.

HABITS.

HABITATION.

Small numbers of mites were observed during the early summer on the underside of hop leaves. A few strands of web were usually present to begin with, and as the number of mites increased the web became more extensive and was observed frequently to cover, in an irregular manner, the entire underside of the infested foliage. The lower leaves were first attacked, but as infestation increased these leaves, which were severely injured, began to dry and thus forced an upward migration of the mites. By August the entire vines were infested and in severe cases mites were observed upon the surface as well as the underside of the leaves.

PROTECTION.

Inhabiting as they do the underside of the leaves, the mites are well protected from wind and other climatic conditions. Further than this, the web which is spun indiscriminately across the underside of the infested foliage affords the mites much protection. Where the finer mist sprays were used the webs were frequently not penetrated and the mites beneath remained uninjured. This combination of web and leaf affords the mites great freedom from injury. The web of the red spider is spun by either sex, and is at all times carried about by the mite as a guard against falling. It thus becomes scattered over the underside of infested leaves and other objects over which the mites may crawl.

HIBERNATION.

A careful examination, during February and March, 1911, of soil and hop roots taken from fields which were badly injured by the red spider in 1910 failed to reveal any hibernating mites or overwintering eggs. During 1911 the mites were found only upon violets and mallow (*Malva parviflora*) which grew in a flower garden half a mile from the hopyards, but they were observed in considerable numbers the following fall, winter, and spring upon wild morning-glory and mallow in all parts of the hopyards.

It is evident, therefore, that the mites pass the winter upon wild plants in and around the hopyards, as has been found true of the red spider attacking cotton in the Southern States, by Mr. E. A. McGregor of this bureau.

LOCOMOTION.

In order to determine the probable distance that an adult female mite is capable of crawling in one day, experiments were conducted in the laboratory. A sheet of paper 3 by 4 feet was placed in front of a window in a warm room, a female mite placed in the center of the paper, and its progress followed with a pencil for one hour. (See



FIG. 5.—Track of a red spider on blotter, covering a distance of 40 feet 9 inches and representing movements during one hour. Sacramento, Cal., 1912. (Original.)

fig. 5.) In two cases loose soil was placed on the paper. Table II sums up the results.

TABLE II.—*Distance traveled by adult female red spiders in one hour on smooth paper and on loose soil.*

Ex- peri- ment No.	Surface used.	Distance traveled.	Distance gained.
		<i>Ft. in.</i>	<i>Ft. in.</i>
1	Smooth paper.....	22 4	
2	do.....	23 8	
3	do.....	3 7½	2 0
4	Loose soil.....		0 11½
5	Blotting paper.....	20 5	
6	do.....	15 9	
7	do.....	40 9	
8	Packed soil.....	6 2	
	Average for paper.....	21 1	
	Average for loose soil.....		0 11½
	Average for packed soil.....	6 2	

The surface of the paper corresponds very well with that of the hopvine, and at this rate an average female mite is capable of covering 211 feet of vine surface during a period of 10 hours.

In the case of soil, the lumps and sand interfered greatly with progress and were responsible for many changes in direction. The distance gained by these mites in 10 hours varied greatly, approximating 10 to 60 feet from the starting point. The actual distance traveled over soil may in some cases exceed the above where the soil is very smooth and hard, but on rough ground is probably much less.

From the foregoing experiments it seems probable that the mites can travel some distance over the bare soil, thus infesting plants more or less widely removed from those on which they passed the winter.

EMERGENCE FROM HIBERNATION.

First appearance of mites on hops.—The hopvines in yards that were known to be infested during 1910 were frequently inspected for mites during the following spring. The first mite observed upon a hopvine was found April 21 in the center of a yard near Sacramento. This lone mite was surrounded by eight eggs and protected by a small amount of dusty web. No more mites were observed until May 9, when a single mite was discovered on a hopvine situated 100 feet from a fence dividing two large hopyards near Perkins, Cal. Mites were later found upon some early hops which were growing along a fence and were also present in about the same numbers upon hopvines some distance from the borders of the hopyards. The mites gradually increased in numbers, and by June 1 occasional hopvines were found on which the lower leaves harbored from 5 to 33 mites each.

As is shown by the foregoing data, the mites appeared simultaneously in various parts of the hop fields and did not, as was formerly supposed, invade the yards from along the edges and work toward the center of the fields.

MIGRATORY ACTIVITIES.

Before the infestation became severe the mites were observed upon the underside of the lower leaves, over which they had spun a small amount of web. No distinct migration was noted at this time, but as the mites increased in numbers the infested leaves were seriously injured and partially dried. In this condition they furnished very little food and forced the mites to migrate to fresh foliage, leaving behind them from 100 to 450 eggs and at least one-tenth as many larvæ. Gradual upward migrations continued until the last of July, at which time the plants were entirely infested.

During the month of August a new condition was observed. The morning-glory in the hopyards had become seriously injured by mites. A migration caused by the sudden decrease in the food supply was begun and soon became very extensive. Myriads of mites were seen crawling from the dying morning-glory, over the clods, up the vines and trellis poles, and covering everything with a fine web.

A similar condition was noticed on a few hopvines that had fallen from the wire. The leaves that were farthest from the ground were

covered and often connected by a web which appeared reddish-brown or silvery, according to the number of mites present. The mites were frequently found clustered like swarms of bees (Pl. I, figs. 1, 2), and the lower ones in dropping off were blown several inches by the wind.

That migration did not take place during the early part of the season was evidenced by the fact that 26 vines which were planted that season were noted to be free from mites July 25, 1911, while the surrounding older vines were thoroughly infested. Soon after the migrations commenced, however, mites were seen upon these vines.

FOOD PLANTS.

Tetranychus bimaculatus has a remarkably large number of host plants, and as will be seen from the following list, these plants belong to a wide range of families, including glabrous and hirsute plants. For convenience the following list has been divided into three parts. The first part contains a list of greenhouse and ornamental plants attacked by the mites; the second, a list of plants attacked in the field; and the third, a list of plants which were observed to be infested in and around the hopyards in the Sacramento Valley, Cal.

List of food plants of Tetranychus bimaculatus.

Greenhouse and ornamental plants, etc.—Rose, violet, carnation, mignonette, clematis, pelargonium, abutilon, fuchsia, passiflora, manettia, bouvardia, feverfew, verbenas, heliotrope, honeysuckle, hydrangea, salvia, morning-glory, moonflower, cypress vine, phlox, aster, chrysanthemum, dahlia, sunflower, goldenglow (*Rudbeckia* sp.), calla, Easter lily, Boston smilax, mimulus, slipper flower (*Calceolaria* sp.), canary bird vine (*Tropæolum peregrinum*), thunbergia, wedding bells (*Burmannia arborea*), castor-oil bean, *Asparagus plumosus*, cuphea, godetia, caladium, tomato, cucumber, onion, and sweet pea.

Field plants, shrubs, and trees.—Bean, lima bean, cowpea, pea, cucumber, chayote (*Sechium edule*), cantaloupe, watermelon, squash, celery, eggplant, pepper, tomato, pepino (*Solanum muricatum*), cotton, okra, corn, raspberry, blackberry, table and sugar beets, hops, hemp, alfalfa, clover, peanut, groundnut (*Apios apios*), English ivy, ferns, privet, hollyhock, Kentucky coffee tree (*Gymnocladus canadensis*), wistaria, hop tree (*Ptelea trifoliata*), pecan, ornamental sassafras, cedar, arborvitæ, Colorado blue spruce, maple, horse-chestnut, Carolina poplar, and birch.

Host plants in and near hopyards.—Mat-grass (*Lippia nodiflora*), *Amaranthus blitoides*, hedge mustard (*Sisymbrium officinale*), wild sunflower (*Helianthus lenticularis*), alkali mallow (*Disella hederacea*), *Persicaria lapathiflora* (perennial of *Persicaria*), rough pigweed (*Amaranthus retroflexus*), prickly lettuce (*Lactuca scariola*), blessed thistle (*Oniscus benedictus*), alfalfa (*Medicago sativa*), burdock (*Arctium lappa*), burr clover (*Medicago hispida*), wild morning-glory (*Convolvulus* sp.), and cheese weed (*Malva parviflora*). It has also been observed on Jamestown or Jimson weed (*Datura stramonium*), ironweed, Jerusalem-oak weed, wild geranium (*Geranium memlatum*), and *Ligustrum amurense*.

From the foregoing list it is evident that this mite is nearly omnivorous¹ so far as plant life is concerned, and without doubt there are many other food plants not included in this list.

¹ It is more than likely, since its feeding habits are of a suctorial nature, that this mite will thrive upon nearly any form of vegetation in which the pubescence of the underside of the leaf is not so heavy or luxuriant as to prevent its direct attack upon the leaf tissue proper.



FIG. 1.—FALLEN HOPVINE, SHOWING CHARACTERISTIC SILVERY WEB AND CLUSTERS OF RED SPIDERS (*TETRANYCHUS BIMACULATUS*), INDICATED BY ARROWS. (ORIGINAL.)



FIG. 2.—FALLEN HOPVINES, SHOWING SILVERY WEB, ON WHICH RED SPIDERS ARE CLUSTERED. (ORIGINAL.)

WORK OF THE RED SPIDER ON HOPS.



FIG. 2.—MALE HOPVINE UNINJURED BY THE RED SPIDER. (ORIGINAL.)

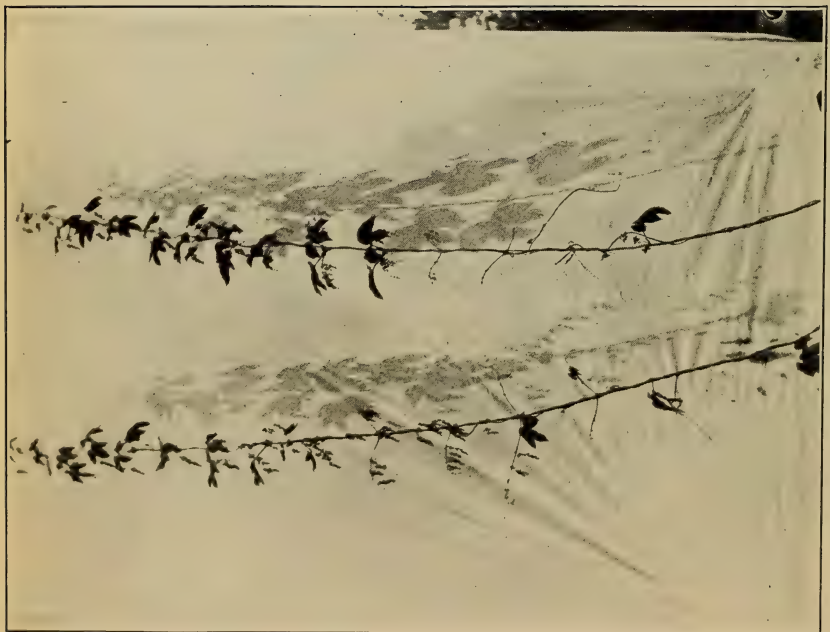


FIG. 1.—MALE HOPVINE INJURED BY THE RED SPIDER. (ORIGINAL.)

WORK OF THE RED SPIDER ON HOPS.

NATURE OF DAMAGE.

GENERAL EFFECT OF MITES UPON FOLIAGE.

These mites feed upon the juices and cell contents which they suck from the tissues of the host plant. This extraction of cell contents usually results in the formation of a light spot at the point where the mite has fed. The presence of mites upon a vine during the early summer is readily detected by these yellow spots in the surface of the leaves. As the mites increase in numbers the leaves become more "speckled," turn yellowish, and when severely injured dry up and fall to the ground. Severely infested vines, at the time that the hop cones are forming, were observed to be very yellow and to lose many leaves.

The decrease in the vitality of the vine, which is the direct result of the attack by mites, produces a premature ripening of the hops. The hop cones in infested yards were much further advanced than those in uninfested hopyards under similar soil and climatic conditions. This premature ripening results in a decrease in yield and a weakening of the roots, tending to decrease the crop of the following year.

RELATIVE EFFECT OF MITES UPON MALE AND FEMALE HOPVINES.

The male vines throughout the season showed more immediate and serious injury than the surrounding female vines. In many cases they were almost entirely defoliated (Pl. II, figs. 1, 2), while the neighboring female vines were but slightly injured.

Some leaves which expanded late in the season on the lower parts of the pistillate vines were thin and papery, appearing identical in texture with the leaves of the male vine, and showed an injury similar to that of the male foliage. This severe injury to the male vines appears to be due largely to the nature of the foliage and not to the presence of a larger number of mites than are found upon the female vines.

EFFECT UPON THE QUALITY OF THE HOPS.

Although the foliage upon the arms of the vines was infested at the time the hops were coming out of the burr, the mites were not observed actually to feed upon them until they were nearly full-sized. No direct injury was noted when the mites were first found upon the cones, but soon reddish-brown spots appeared upon the scales and gradually the natural green and yellow turned to reddish brown, the scales became scraggly, and in severe cases the hop cones became so brittle that they could not be picked. (See Pl. V, fig. 1.)

Even when they can be picked the quality is often severely injured. Dr. W. W. Stockberger, of the Bureau of Plant Industry, reports upon some samples of "spider hops" as follows:

Of these No. 1 is, I should say, practically unsalable. Not only is the color very poor, but it is not uniform and shows very evidently the red discoloration produced by the activities of the "spider." The aroma is also far from pleasing. The second sample, which showed some damage by the spider, is far from being a first-class hop; it of course is still marketable.

Thus, even though a large crop is harvested its value may be greatly reduced by the injury due to the attack of the red spider.

EFFECT UPON MAN.

Some of the workmen of the hop ranches stated that during hop picking they had been troubled by the mites getting upon their bodies and causing an irritation. This point was investigated; several hundred mites were liberated upon the hands and arms of the writer and allowed to crawl around for 20 minutes. A barely detectable itching was the only sensation observed. The irritation mentioned by the men was probably due to scratches of the hop-vines and not to any irritation caused by mites.

DISTRIBUTION IN THE FIELD.

It was the opinion of some hop growers that the red spider appeared first along the roads and fences and gradually worked into the fields, but observations in several localities did not bear out this point. The mites first appeared within the hopyards and not especially along the borders, and although the increase was rapid, the infestation was evenly distributed.

The dust from the roads collecting on the foliage made the web show very distinctly, and the growers, judging the extent of an infestation by the amount of web that can be seen, would naturally think that the infestation started where the web was most noticeable. This accounts for the erroneous opinion mentioned above.

Mr. W. H. Volek, who made some observations upon the red spider at Wheatland, Cal., in 1902, suggested that since the infestation was so sudden the mites might possibly have traveled through the air on webs, like the "balloon" spiders. To test this point four dozen sheets of tanglefoot fly paper were tacked to the trellis poles in various parts of the infested yards at Perkins, Cal. They were put out in June, 1911, and when collected in September many insects were found embedded in the hardened tanglefoot, but no mites were observed. During the migrations in August mites dropping from

the clusters were blown from 6 to 8 inches from where they would naturally drop, but it is very unlikely that they are carried any distance by any but a very strong wind.

The only probable means of distribution other than the natural migrations are by horses used in cultivating, or by the hands and clothing of the men, and possibly on the bodies of the larger insects found on the hopvines.

PREDACEOUS ENEMIES.

Several predaceous insects were observed destroying red spiders on the hopvines near Sacramento, Cal., but their numbers were insufficient to have any effect upon the infestation. The most numerous predaceous insect was a small anthocorid bug (*Triphleps tricolor* White). This insect, both in the nymphal and adult stages, was very common in some sections of the yards and was frequently seen feeding on the mites.

Certain small ladybirds have been noticed preying upon this species in infested yards, but were not found in large numbers. Among these are the following:

Scymnus nanus Lec., observed at Sacramento, Cal., July, 1911.

Scymnus marginicollis Mann., observed at the same time and place.

Pentilia sp., found in some infested yards but present only in small numbers.

During July *Chrysopa californica* Coq., in the larval stage, was very abundant and probably did more good than all the rest of the predaceous insects together.

Dr. F. H. Chittenden¹ reports (*Scymnus*) *Stethorus punctum* Lec., *Cecidomyia coccidarum* Ckll., *Aphanogmus varipes* Ashm., *Chrysopa rufilabris* Burm., and (*Thrips*) *Scolothrips sexmaculatus* Perg. as feeding upon the red spider at Washington, D. C., and elsewhere.

Mr. E. A. McGregor,² an agent of this bureau, has recorded the following natural enemies of the red spider on cotton at Batesburg, S. C., in 1912:

Triphleps insidiosus Say.

Chrysopid larvæ.

Euthrips fuscus Hinds.

Euthrips occidentalis Perg.

Scolothrips sexmaculatus Perg., recorded by both Pergande and Duffy.

Coccinella 9-notata Hbst. (larvæ).

Hippodamia convergens Guer. (larvæ).

While predaceous insects destroy many of the mites in the hop fields, their work has no appreciable effect upon the infestation.

¹ The common red spider, Cir. 104, Bur. Ent., U. S. Dept. Agr., 1909.

² The red spider on cotton, Cir. 150, Bur. Ent., U. S. Dept. Agr., 1912.

EXPERIMENTS FOR THE CONTROL OF THE RED SPIDER.

METHODS OF EXPERIMENTATION.

The sudden and widely distributed appearance of the red spiders in the hopyards, the rapidity of their increase, and the fact that the old remedy (sulphur) had not controlled the mites in the hopyards during the preceding season made the control problem appear a difficult one. As soon as the mites became numerous enough on the hopvines to warrant experimental work, the first of a long list of experiments which was planned during the spring of 1911 was applied. The lime-sulphur solutions, because of their efficiency and relatively low cost, soon became the most promising of the contact insecticides. They were therefore applied more extensively and were given more attention than the other materials which were listed during the investigation.

The materials were applied, except in the small-scale work, with a power outfit (Pl. III, fig. 1) which maintained from 120 to 150 pounds pressure. Seven-foot rods tipped with a nozzle throwing a fine but washing spray were used for the work.

In making the tests with the various insecticides it was found desirable to express their efficiency with as near an approach to numerical exactness as possible. Tag counts and field counts were employed in obtaining the percentage of mites killed and were found to be very accurate. In most cases only one of these methods was used on a plat, but occasionally both were employed. These counts were made both before and after spraying.

Tag counts.—Twenty tags were attached to the petioles of as many leaves, and the numbers of mites found upon the several leaves, both before and after spraying, were recorded upon the attached tags. The percentage of mites killed by the spray was thus very accurately obtained.

Field counts.—Field counts were made by picking 20 leaves from various parts of as many vines chosen throughout the plat. The numbers of mites found upon the leaves, which were taken both before and after spraying, were compared and the percentage of mortality obtained. This method gave a good idea of field conditions but did not prove as effective as the tag count.

SULPHUR.

Sulphur in a dry and finely divided form has in past years been used very extensively against red spiders with supposedly good results. One experimenter states that although the sulphur does not affect the adult mites, it kills the larvæ when they emerge from the eggs and thus checks the infestation. Several hop growers stated that the red



FIG. 1.—SPRAYING HOPVINES WITH POWER OUTFIT. (ORIGINAL.)



FIG. 2.—APPLYING PRECIPITATED SULPHUR IN DUST FORM AS
A REMEDY AGAINST THE RED SPIDER. (ORIGINAL.)

SPRAYING AND DUSTING FOR THE RED SPIDER
ON HOPS.



FIG. 1.—SWEET PEAS INFESTED BY THE RED SPIDER, BUT PROTECTED BY DUSTING, AT INTERVALS OF ONE WEEK, WITH PRECIPITATED SULPHUR. LOS ANGELES, CAL., 1910. (ORIGINAL.)

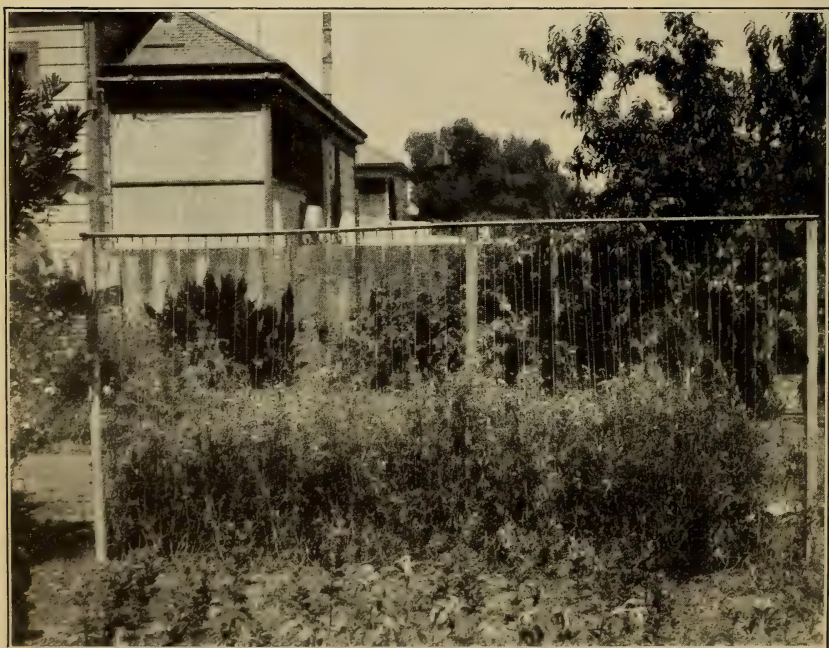


FIG. 2.—SWEET PEAS, GROWTH ABORTED, BLOSSOMS INDIFFERENT, AND VINES NEARLY KILLED BY THE RED SPIDER. LOS ANGELES, CAL., 1910. (ORIGINAL.)

THE RED SPIDER ON SWEET PEAS.

spider could be easily controlled; that sulphur dusted or blown onto the vines would soon check their progress. General observations made in the infested fields that were thoroughly dusted with finely powdered sulphur, however, lead the writer to believe that dry sulphur is of no value whatever in checking the ravages of this mite upon hops. This point was most conclusively proved, as will be seen from the following data.

In testing the efficiency of this material upon the mites, all the available forms of dry sulphur were purchased and a precipitated form was prepared by treating a lime-sulphur solution with hydrochloric acid. These sulphurs were applied in the form of dust (Pl. III, fig. 2) and also with water as a "wet spray." Table No. III gives results which were obtained from tag counts taken at various times during the season of 1911 and 1912.

TABLE III.—*Negative results produced by sulphur in various forms used against the red spider on hops.*

Date.	Material.	Number of mites present before.	Number of mites killed by application.	Per cent of mites killed by application.	Days between application and third count.	Number of mites, third count.	Increase of mites.	Per cent of increase.
1911.								
June 30	Precipitated sulphur, 10 pounds; flour paste, 4 pounds; water, 100 gallons.	271	-----	-----	10	282	11	4.06
July 15	Flowers of sulphur, 20 pounds; water, 100 gallons.	201	61	69.7	26	1,458	1,257	625.00
18	Precipitated sulphur, 10 pounds; water, 100 gallons.	264	146	55.3	21	1,533	1,269	480.68
18	do.	305	163	53.4	(¹)	(¹)	(¹)	-----
25	Precipitated sulphur dust, applied dry.	560	-----	-----	21	670	110	19.64
1912.								
July 10	Precipitated sulphur dust.	638	-----	-----	30	1,198	560	87.77

¹ Tags lost after second count.

Mites of all ages (larvæ, nymphs, and adults) were observed from time to time on the tagged leaves.

This table definitely illustrates the inefficiency of sulphur in controlling the red spider on hops. It will be noted that a certain percentage of mites was killed or washed off by the spray, but the increase which followed proves definitely that sulphur in the dry form has little or no effect upon the mites. Observations in fields where sulphur had been applied by hand and by a traction dust machine also bore out this statement. In some cases there were few mites upon the sulphured vines, and growers claimed that the sulphur had destroyed the mites. Near-by unsulphured foliage, however, was invariably found to be as free from mites as the "sulphured" vines, and this assumption did not hold.

Sulphur as a control of the red spider on hops has been tested and found wanting and is superseded by the contact insecticides.

Reason for inefficiency.—Some experiments with sulphur upon *Tetranychus bimaculatus* attacking prune, pumpkin, and sweet peas proved very satisfactory. Similar results were obtained when sulphur was applied to infested sweet peas in Los Angeles, Cal., by Mr. H. M. Russell, as is shown in Plate IV, figures 1 and 2. The efficiency of sulphur against the red spider on these plants and its inefficiency when applied on hops and cotton led to some careful observations as to conditions. It was noted that the pumpkin and sweet peas expose nearly all of both surfaces of their leaves to the direct rays of the sun at some time during the day and that the mites on the prune were attacking the upper and therefore the exposed surfaces. The hopvines and cotton plants, however, expose principally the upper surfaces of the leaves to the sun and the mites living upon the undersides are thus protected.

From these observations it is evident that sulphur is effective upon the red spiders only when the infested surfaces of the plant are exposed to direct sunshine at some time during the day or to intense reflected heat.

LIME-SULPHUR SOLUTIONS.

The results obtained in a small preliminary field experiment in which lime-sulphur in combination with nicotine sulphate, 40 per cent, was applied gave such good results that these materials were at once placed at the head of the list of sprays to be fully tested out during the course of the investigation. The lime-sulphur solutions are much cheaper than the nicotine solutions when used at the summer dosage; therefore it seemed desirable to try the lime-sulphur solution alone in order to reduce the cost of spraying, provided the omission of the more expensive nicotine solution did not alter the results.

During the early work with these sprays it was evident that the straight lime-sulphur solutions, instead of spreading out in a film, formed beadlike drops on the foliage. Mites found in actual contact with these drops of spray were seen to draw away from them and escape uninjured. The results obtained with straight lime-sulphur solutions were most unsatisfactory.

Soap formed a precipitate with the polysulphid, and as it was very evident that some "spreader" must be used if the lime-sulphur solutions were to prove effective, this subject was thoroughly investigated.

Upon the suggestion of Prof. A. L. Quaintance, of this bureau, "black-strap" molasses, a cheap grade, was used with the lime-sulphur spray at the rate of 2 gallons to 100 gallons of spray. This

mixture spread more rapidly than the straight solutions, but did not prove entirely satisfactory.

While applying a spray composed of lye-sulphur, flowers of sulphur, and flour paste, it was observed that the material spread over the leaves very rapidly. This flour paste seemed to meet the demand for a "spreader" and was accordingly mixed with the lime-sulphur solutions. The result was a smooth mixture, without precipitate, which spread over the leaves in a most effective manner (Pl. V, fig. 2) and gave unusually effective results as an insecticide. The proper proportions were found, on experimentation, to be 4 gallons of flour paste (4 pounds of flour) to 100 gallons of spray.

Lime-sulphur and flour paste proved a very effective and relatively cheap spray for use against the red spider and was extensively used in the control work carried on in the Sacramento Valley in 1911.

TABLE IV.—*Spraying experiments with lime-sulphur solutions against the red spider on hops.*

No.	Date.	Material.	Applica- tion.	Number of mites present.	Number of mites killed.	Per cent of mites killed.	Per cent of mites killed after sev- ond applicat-on.	Cost per 100 gal- lons.	Count.	Effect on vine.
1	June 23	Lime-sulphur, 36° Baumé, 1-75 1.	Thorough.	360	135	37.5	.....	\$0.26	Tag.	None.
2	27	Lime-sulphur, 36° Baumé, 1-75; flour paste, 4-100.	...do.....	698	692	99.0	.....	.35	...do.	Do.
3	July 1	Lime-sulphur, 36° Baumé, 1-50; flour paste, 4-100.	...do.....	697	691	99.0	.....	.49	...do.	Slight in- jury.
4	5	Lime-sulphur, 36° Baumé, 1-60; flour paste, 4-100.	...do.....	964	945	98.1	.....	.51	...do.	Do.
5	6	Lime-sulphur, 36° Baumé, 1-86; flour paste, 4-100.	...do.....	593	534	90.0	97.1	.32	...do.	None.
6	6	Lime-sulphur, 36° Baumé, 1-86; flour paste, 4-100.	...do.....	593	586	98.8	.....	.32	Field	Do.
7	9	Lime-sulphur, 36° Baumé, 1-100; flour paste, 4-100.	...do.....	906	892	98.4	.....	.29	Tag.	Do.
8	19	Lime-sulphur, 33° Baumé, 1-70; flour paste, 4-100.	...do.....	143	142	99.7	99.7	.38	...do.	Do.
9	19	Lime-sulphur, 33° Baumé, 1-70; flour paste, 4-100.	...do.....	509	440	86.4	92.9	.38	Field	Do.
10	19	Lime-sulphur, 33° Baumé, 1-70; flour paste, 4-100.	Careless...	509	55	10.8	.....	.38	...do.	Do.

¹ The terms "lime-sulphur, 1-75," "flour paste, 4-100," etc., denote 1 gallon of lime-sulphur to 75 gallons of water, 4 gallons of flour paste to 100 gallons of water, etc.

NOTE.—The amount of material necessary per acre varies from 300 gallons in light foliaged hops to 500 gallons in heavy foliaged hops.

Table IV gives an accurate conception of the efficiency of the lime-sulphur-and-flour-paste spray. The percentages obtained in Nos. 1 and 2 of this table represent graphically the relative efficiency of lime-sulphur solutions with and without the flour paste. A great difference in the percentage is again noted in Nos. 9 and 10. In No. 9 the material was thoroughly applied and in No. 10 applied very carelessly. The lower percentages obtained late in the season as compared with the higher percentages secured earlier in the season are due to

the condition and extent of the foliage on the vines. During the early part of the work the foliage was light and could be easily sprayed, while later on it became dense, and thorough work was quite difficult. The results, however, prove the efficiency of the lime-sulphur-and-flour-paste spray in killing the red spider on the hopvine.

FLOUR PASTE.

The efficiency of flour paste as an arachnicide was indicated in the experiment which is recorded under No. 14 of Table VII, but it was not until the summer of 1912 that its value was fully realized. During spraying experiments with nicotine sulphate and flour paste upon the hop aphid it was observed that many of the smaller aphides had become pasted to the leaves. From this data it was assumed that a solution containing a larger proportion of flour paste should be effective against the more delicate aphides and mites, and the following experiments were accordingly conducted upon the red spider on hops:

TABLE V.—*Experiments with flour paste against the red spider on hops.*

Date.	Formula.	Number of mites present.	Per cent of mites killed.	Cost per 100 gallons.
June 18.....	Flour paste, 8-100.....	435	100.0	\$0.176
June 27.....	do.....	781	99.8	.176
July 12.....	do.....	452	99.8	.176
Aug. 6.....	do.....	882	100.0	.176
Do.....	do.....	477	100.0	.176
Aug. 9.....	do.....	908	99.8	.176
	Total.....	3,759	¹ 99.9	.....
July 16.....	Flour paste, 10-100.....	805	99.9	.22
Aug. 6.....	do.....	908	99.9	.22
	Total	1,712	¹ 99.9	.....

¹ Average.

These experiments prove that the flour paste, 8-100 and 10-100, is effective against *Tetranychus bimaculatus*. The spray pastes the mites onto the leaves, but has no effect upon the eggs, and in controlling the mites a second application is necessary.

The neutrality of this spray was proved by the fact that when applied upon the foliage and blossoms of the hop, in proportions as high as 12 gallons of paste to 100 gallons of spray, no injurious effects resulted. When sprayed onto the burrs and delicate hop cones, it did not prevent pollination or injure the appearance of the scales.

When mixed in the spray tank, flour paste has a tendency to settle, and in order to do satisfactory work agitation is necessary. It is,



FIG. 1.—UPPER ROW: LARGE, FULL-SIZED, HEALTHY HOPS. LOWER ROW: SMALL, ROUGH HOPS, SHOWING LOSS IN WEIGHT DUE TO THE RED SPIDER. (ORIGINAL.)



FIG. 2.—LEAF OF HOP, THE LEFT HALF OF WHICH WAS SPRAYED WITH LIME-SULPHUR AND FLOUR PASTE, AND THE RIGHT HALF WITH LIME-SULPHUR ALONE. (ORIGINAL.)

Note that the spray is uniformly distributed on the left half of the leaf; on the right half, however, it is collected in separate drops or patches, owing to the pubescence of the leaf.

however, an effective, convenient, and nonoffensive spray, and the cheapest one that has been successfully used against the red spider.

LYE-SULPHUR.

The lye-sulphur solution (Formula No. 1), used with success against the red spider on the almond by Mr. W. H. Volek, was applied with flour paste and with cresol soap in various proportions. The results of these experiments (Table VI) were obtained from tag counts and are very promising.

The lye-sulphur solution, used with either the cresol soap or the flour paste, was very effective, and when used in the proper proportions did not injure the foliage in the least. It would have been used more extensively in field experiments had not the lye been disagreeable to handle in making up the stock solution. The lime-sulphur on the market at a relatively low figure proved just as effective as the lye-sulphur and, being much more convenient, was preferred.

TABLE VI.—*Spraying experiments with lye-sulphur in various combinations against the red spider on hops.*

No.	Date.	Material.	Applica- tion.	Num- ber of mites present.	Num- ber of mites killed.	Per cent of mites killed.	Cost per 100 gallons.	Effect on vine.
1	June 23	Lye-sulphur, 4-100; cresol soap, 1-300.	Thorough.	377	367	97.4	\$1.05	Slight injury.
2	June 26	Lye-sulphur, 2-100; sulphur, 15 pounds to 100 gallons; flour paste, 4-100.	...do.....	374	366	97.8	.708	No injury.
3	July 2	Lye-sulphur, 1-100; sulphur, 15 pounds to 100 gallons; flour paste, 4-100.	...do.....	371	361	97.4	.55	Do.
4	July 15	Lye-sulphur, 1-100.....	...do.....	518	458	88.5	.15	Do.
5	...do....	Lye-sulphur, 2-100.....	...do.....	437	384	87.8	.31	Do.

Although the lime-sulphur, or lye-sulphur, and flour-paste solution did not injure the foliage or the blossoms of the hopvines, it did injure the more tender hop cones. The late spraying with lime-sulphur, if practiced, should be completed before the hop cones come out from the burr.

NICOTINE SOLUTIONS AND OTHER MATERIALS.

The nicotine solutions, used with the lime-sulphur, or with soap, or alone, were quite expensive, as may be seen in Table VII. The lime-sulphur and flour paste was so much cheaper and so effective that the nicotine experiments which had been outlined were conducted on a small scale only. The results of these experiments, together with the results of some miscellaneous experiments, are given in Table VII.

TABLE VII.—*Spraying experiments with various combinations against the red spider on hops.*

No.	Date.	Material.	Application.	Number of mites present.	Number of mites killed.	Per cent of mites killed.	Cost per 100 gallons.
1	July 15	Nicotine sulphate, 40 per cent, 1-750..	Thorough, but beaded.	450	263	58.4	\$1.66
2	do.....	Nicotine sulphate, 40 per cent, 1-1,000.	do.....	414	376	90.8	1.25
3	do.....	Nicotine sulphate, 40 per cent, 1-2,000.	do.....	762	677	98.9	.62
4	do.....	Nicotine sulphate, 40 per cent, 1-3,000.	do.....	414	263	63.6	.416
5	July 16	Nicotine sulphate, 40 per cent, 1-60.....	do.....	237	185	78.1	1.08
6	do.....	Nicotine sulphate, 40 per cent, 1-2,000; lime-sulphur, 1-86.	do.....	312	273	87.5	.85
7	do.....	Nicotine sulphate, 40 per cent, 1-3,000; lime-sulphur, 1-86.	do.....	361	280	78.6	.64
8	do.....	Nicotine sulphate, 40 per cent, 1-750; cresol soap, 1-300.	Thorough, not beaded.	330	225	68.3	2.08
9	do.....	Nicotine sulphate, 40 per cent, 1-1,000; cresol soap, 1-300.	do.....	164	111	67.7	1.67
10	July 17	Nicotine sulphate, 40 per cent, 1-2,000; cresol soap, 1-300.	do.....	269	174	64.7	1.04
11	do.....	Nicotine sulphate, 40 per cent, 1-3,000; cresol soap, 1-300.	do.....	201	115	57.2	.83
12	do.....	Lime-sulphur and nicotine sulphate, 1-50.	Thorough, but beaded.	273	191	70	.....
13	do.....	Lime-sulphur and 40 per cent nicotine sulphate, 1-50; flour paste, 4-100.	Thorough, not beaded.	163	157	96.3	.....
14	do.....	Flour paste, 4-100.	do.....	657	444	67.5	.09

PURE WATER.

Spraying with water is one of the most successful and most commonly used methods of controlling the red spider in greenhouses. With a strong but fine stream of water the mites are washed from the foliage of infested plants and the infestation is reduced to a minimum.

It was thought possible to wash the mites from the hop leaves by spraying water through a coarse nozzle at 200 pounds pressure with about as successful results. This experiment was accordingly carried out, and although some of the mites were washed off, many were left and were later seen to have been uninjured by the force of the spray.

The lime-sulphur-and-flour paste and the flour paste, 8-100, are so cheap that even though between 50 and 70 per cent of the mites could be killed by pure water, one of the former materials, which destroys about 98 per cent, is preferred.

VALUE OF A SECOND APPLICATION.

After a few spraying experiments had been conducted it was seen that the sulphur, the lime-sulphur, and the lye-sulphur had no effect upon the mites except by actual contact; therefore the idea of placing a material on the vines which would kill the larvæ on emergence was abandoned. Although nearly 100 per cent of the mites living upon the leaves could be destroyed by the spray, the eggs were uninjured and the newly hatched larvæ reinfested the leaves as badly as before. It was therefore decided to spray a second time after all the eggs had hatched and yet early enough to prevent any larvæ from becoming mature.

During July the mites passed from larva to adult in 8 days and during April the incubation period was 7 to 10 days.¹ Basing the time of a second application on this data, 7 days was decided upon as the interim between the first and second sprayings, and by following out this plan some very encouraging results were obtained, as shown in Table VIII.

TABLE VIII.—*Experiments showing value of a second application in spraying for the red spider on hops.*

No.	Date.	Material.	Applica- tion.	Num- ber of mites pres- ent.	Num- ber of mites killed.	Per cent of mites killed.	Second appli- cation, per cent killed.
1	July 6	Lime-sulphur, 36° Baumé, 1-86; flour paste, 4-100.	Thorough.	593	543	90	97.1
2	July 19	Lime-sulphur, 33° Baumé, 1-70; flour paste, 4-400.	do.....	143	142	99.7	99.7
3	...do.....	Lime-sulphur, 33° Baumé, 1-70; flour paste, 4-100.	do.....	509	440	86.4	92.9

It will be noted that only from 0.3 to 7.1 per cent of the original number of mites present on the vines were present after the second application. The mites which hatched from the few eggs that remained were not sufficient to form the basis for a reinfestation and the work was accordingly considered satisfactory.

Unfortunately some of the plats treated were covered with infested morning-glory vines, which were severely injured by the mites, and which later resulted in a migration that soon reinfested the hop-vines. Morning-glory was not present in one plat, however, and although the applications were made so late that the vines were severely injured, the results to be expected from such a plan were clearly proved. These vines were comparatively free from mites at the end of the season and had a much more healthy color than the vines in the adjoining plats which were used as checks.

FORMULAS FOR SPRAYS.

To prepare the flour paste, mix a cheap grade of wheat flour with cold water, making a thin batter without lumps; or wash the flour through a wire screen with a stream of cold water. Dilute until there is 1 pound of flour in each gallon of mixture. Cook until a paste is formed, stirring constantly to prevent caking or burning. Add sufficient water to make up for evaporation. (See Pl. VI, fig. 1.)

For spraying with flour paste alone, use 8 gallons of paste as prepared above to each 100 gallons of water.

For the flour-paste and lime-sulphur spray, use 4 gallons of paste to each 100 gallons of spray containing the lime-sulphur.

¹ In moderate weather allow 10 and in hot weather 7 days between applications.

BANDING WITH TANGLEFOOT.

Banding with tanglefoot has become the chief method of controlling the hop flea-beetle (*Psylliodes punctulata* Melsh.) in British Columbia, and as the mites also work up the vine mainly by crawling it was deemed advisable to attempt to check their progress by means of the tanglefoot bands. In order to test this method, 10 infested

hopvines were selected. A few leaves were removed to prevent bridging, and in some cases the vines were stripped; tree tanglefoot was then applied to the vines in 3-inch bands. (See fig. 6.) About 20 badly infested leaves were next attached to the vines below the bands and the lower parts thus thoroughly infested. During the following week these vines were continuously observed. Hundreds of mites were found around the lower edges of the bands, and in cases where the lower leaves had been stripped off some web was found at the base of the tanglefoot, but there was no evidence that the mites had crossed over. Although mites were seen above the bands, these probably were carried there on the observer's hands during previous observations.

Similar experiments were conducted in 1912, except that some foliage was left below the bands on which the mites could multiply and from which they could migrate.



FIG. 6.—Hopvines banded with tanglefoot, in an attempt to prevent the mites from ascending. (Original.)

Three weeks' observation failed to reveal mites above properly banded vines, but after this time the tanglefoot became filled with sand and was not effective.

One large-scale experiment with tanglefoot was attempted, but the work was done so late in the season that a few mites were already above the point of banding and no definite results could be obtained.

Banding with tanglefoot in itself will probably not act as a control for the red spider, but in yards where late clean culture is not practicable it will probably protect the sprayed vines from the late summer migrations.

Application.—It is necessary to get the tanglefoot well into the spaces between the two vines, the simplest way to accomplish this



FIG. 1.—COOKING FLOUR PASTE OUT OF DOORS; KILN-HOUSE FOR DRYING HOPS, PREPARATORY TO BALING, IN DISTANCE. (ORIGINAL.)



FIG. 2.—LARGE POWER SPRAYING OUTFIT, SHOWING LINES OF HOSE RUNNING INTO HOPYARD. (ORIGINAL.)

SPRAYING FOR THE RED SPIDER ON HOPS.

being with the hands. A section about 3 inches long should be coated with the tanglefoot, care being taken that no parts are missed and that no leaves are left to form a bridge across it. Although the tanglefoot is apparently very disagreeable material to apply, it is easily washed off the hands with a little kerosene or even with soap and hot water.

METHODS OF APPLYING SPRAYS.

No spraying for the red spider should be attempted unless the proper appliances and machinery are at hand. Hand pumps which will maintain 150 pounds pressure can be used, but power outfits are preferable. Traction and compressed-air sprayers which will maintain the proper pressure are light, convenient, and readily hauled through the hopyards, but unless the required pressure is maintained they will not give satisfactory results in spraying. The outfits used in the experimental work at Sacramento were composed of a gasoline engine, a spray pump, and a 50-gallon barrel mounted upon a light three-wheeled truck. These outfits did effective work, but carried so little spray material that they required refilling entirely too often. A large orchard power outfit (Pl. VI, fig. 2) equipped with two 150-foot lines of hose was operated around the edges of some of the yards with good results. The driver assisted the rodmen in getting the hose in and out of the rows and a wide strip around the yards was treated. In cases where the infestation appears on one side of a field such machines can be readily employed.

The mites are almost entirely found on the underside of the leaves, and in order to wash them thoroughly the spray must be directed from below. When angle nozzles are not available the spray rod may be bent so that the spray may be readily directed to the underside of the leaves. If one or the other of these methods is not employed the material will not be satisfactorily applied.

In order to penetrate all of the webs and reach all of the mites it is necessary to use a nozzle that will throw a washing rather than a mist spray. The Bordeaux or "stopcock" type is usually too coarse and wastes material, so that a nozzle should be chosen somewhere between that and the Vermorel type. Some of the recent makes can be regulated by the alteration of the size of the opening in the disk so that any degree of spray can be obtained. Such nozzles are very well adapted to the red-spider work.

In controlling the red spider in the hop fields it is necessary that a large territory be covered in a short time and that the material be applied very thoroughly. To do this several outfits are necessary and these must be in good working condition. Disabled machinery not only increases the expense of spraying but reduces the chance of controlling the mites.

COST OF SPRAYING.

The following estimate of the cost of spraying for the red spider is made from data taken from actual field work on high-trellis yards. The amount of material needed for hops on short poles will be somewhat less.

It has been found that one machine will spray from 2 to 3 acres per day and that in order to do thorough work it is necessary to apply from 300 to 500 gallons per acre, according to the amount of foliage on the vines. The following data are based on a machine which will spray 2 acres per day.

TABLE IX.—*Cost of spraying hopyards for the red spider.*

	Cost of application per acre.			
	Flour paste, 8-100; cost and cooking, 19 cents per 100 gallons.		Lime sulphur, 1-100, and flour paste, 4-100; cost per 100 gallons, 26 cents.	
	300 gallons.	500 gallons.	300 gallons.	500 gallons.
Labor: 3 men at \$2 per day for one-half day	\$0.57	\$0.95	\$0.78	\$1.30
1 horse at \$0.50 per day for one-half day	3.00	3.00	3.00	3.00
	.25	.25	.25	.25
Total cost	3.82	4.20	4.03	4.55
Cost of two applications	7.64	8.40	8.06	9.10

The cost of stripping the vines preliminary to spraying will be from \$1.80 to \$2 per acre.

Comparing the cost of spraying for the red spider with the loss that may result from its ravages, it is evident that money spent in controlling this mite will be well invested.

CULTURAL METHODS.

Stripping the vines.—The practice of stripping the vines is a common one in regions where the hop aphid (*Phorodon humuli* Schrank) is troublesome. A large amount of aphid-breeding foliage is cleared from the vines and only the more readily sprayed leaves are left.

In experimenting along this line several vines were stripped and tied together at various points to determine which method would most readily facilitate spraying. The lower foliage on vines which were not stripped but were tied together 4 feet from the ground (fig. 7) was found to be matted and very difficult to spray thoroughly. When the lower 3 feet of the vines were stripped and the two vines tied at the 4-foot mark (fig. 8), 1 foot of the vine was still in a condition difficult to spray. But when stripped and tied a few inches below the lower leaves (fig. 9), the vines spread out nicely and the

leaves were readily sprayed. It is always difficult to spray thoroughly, and any cultural method which will facilitate effective work is worth while. During the early part of the seasons of 1911 and 1912 the mites were observed upon the lower leaves only and from there migrated upward. It is estimated that the stripped area contains about 40 or 50 leaves; taking the average number of mites as 42



FIG. 7.—Hopvine tied high and not stripped; lower leaves difficult to spray. (Original.)

per leaf for an average infestation, the theoretical number of mites that would be removed would be about 1,680 or 2,100 per vine.

One hopyard which was stripped before the mites were above the point to which the vines were to be stripped was observed August 9. It was found that the infestation had been materially checked.

It is believed that timely stripping of the vines and removal and burning of the infested leaves will severely check the infestation and in some cases where the yards are not filled with food plants will

successfully control the mites. Too much faith should not be placed in this operation, however, as spraying may have to be resorted to as a final measure. The cost of stripping is about \$2 per acre and is more than offset by the results obtained.

Irrigation.—Vines which have not a large supply of moisture dry and change color more rapidly than those growing in moister soil, so that the work of the red spider is most noticeable on light soil in



FIG. 8—Hopvine tied high and stripped; lower leaves matted and difficult to spray. (Original.)

the drier parts of the hopyards. Several growers, believing that irrigation of the infested vines would counteract the effect of the mites, pumped water onto their yards and gave the soil a thorough wetting. The vines responded and put out a few fresh leaves, but the mites infested these in the same manner as before and reduced the quality of the hops in the same proportion as on unirrigated and equally infested parts of the adjoining hopyards. Irrigation will not control the mites, but when the soil lacks sufficient moisture it will

stimulate the vines, causing them to put out some fresh foliage so that the loss in weight of the hops will not be so great as it would be otherwise.

Fertilization.—In parts of the hopyards where the vines were very vigorous, as a result of fertilization, the presence of mites was not so noticeable as in parts where the foliage was not so dense. The increase of mites was just as rapid, however, and at the end of the season the densely foliaged vines were just as badly injured, and the



FIG. 9.—Hopvine tied low and stripped; leaves readily sprayed. (Original.)

hops in many cases were discolored. The denser foliage gives a larger surface to be injured, and with equal infestation plats with light foliage will necessarily be more seriously injured than the denser ones.

Fertilization will increase the vigor and the productiveness of the hopvines and, while it will not in any way control the mites, it should be practiced on general principles.

Although the red-spider injury is relatively not so great on vines invigorated by fertilization, it is present and will be extensive according to the severity of the infestation.

Clean culture.—In September, 1911, a block in an infested hopyard was carefully cleared of all vegetation in an attempt to destroy all of the mites present. When examined October 16, however, a few mites were observed on some morning-glory which had come up since the plat was cleared. The practice of clean culture is very important and has a great influence upon an infestation, but it can not be relied upon as a complete control.

GENERAL SUMMARY WITH RECOMMENDATIONS.

The investigation of the control of the red spider on hops has brought out the following points:

Great financial loss may be caused by the red spider.

The mites on hops are *not affected by any form of dry sulphur*, but are readily killed by several contact insecticides, the cheapest and most convenient of which are flour paste (8-100) or a combination of lime-sulphur, 36° Baumé (1-100), and flour paste (4-100). To get the best results it is essential that the vines should be thoroughly sprayed.

Stripping the vines and burning the leaves is an excellent measure, but should not be entirely relied upon as a complete control. When the infestation is severe early in the season and the mites are above the point of stripping, spraying operations should be commenced as soon as the vines are stripped.

The infested area must be *thoroughly and rapidly covered* and must be sprayed a second time, 7 or 10 days later.

Banding with tree tanglefoot will check migrations and is recommended where the hopyards are infested by food plants of the red spider.

Two later spray applications may be necessary if the mites again appear in injurious numbers.

The red spider on the hopvine may be economically controlled if the foregoing measures are carefully carried out.

CONTROL OF THE RED SPIDER UPON PLANTS OTHER THAN HOPS AND COTTON.

The flour paste, 8-100, as described on pages 24 and 27 of this bulletin, is a successful remedy for the control of the red spider in its attacks on all plants except sweet pea, carnation, greenhouse roses, and plants having a heavy pubescence on the leaves. Experiments have been conducted with this material against the mites upon the following plants without the slightest injury to opening buds, foliage, or fruit:

Outdoor plants: Pumpkin, squash, cucumber, roses, violets, box-elder, and bean.

Greenhouse plants: Cucumber, violets, and chrysanthemums.

Judging from the data gathered in the foregoing experiments this spray, when properly used, should control the red spider on all plants except those mentioned in the following paragraphs:

Sweet peas.—The foliage of the sweet pea is very hairy, and that of the carnation and greenhouse rose is so smooth that the flour paste will not stick to it and therefore does not work satisfactorily. The control of mites upon these plants is taken up separately in succeeding paragraphs. The finer forms of sulphur are effective upon the red spider attacking sweet pea (see p. 22) provided that the plants are growing in a warm, sunny place. The sulphur should be thoroughly dusted onto the infested plants, the application being repeated every week or so.

Roses.—Most roses can be sprayed with flour paste, 8–100, but the leaves of roses grown in greenhouses are so smooth and glossy that the paste will not stick to them. The old method of washing them with the garden hose remains as the best remedy in this case.

Carnations.—A weak salt or soap solution is used by some growers as a control for the red spider, but continual spraying with water is the universal method of control.

Use of sulphur.—As stated on page 22, dry sulphur will control the mites upon those plants which expose most of both surfaces of their leaves to the sun during the day, but the flour-paste spray is so cheap, available, and effective that where large areas are involved it is recommended in preference to the sulphur treatment. Sulphur, however, has proved more or less effective upon the squash, pumpkin, sweet pea, and bean.

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DIV. INSECTS.

U. S. DEPARTMENT OF AGRICULTURE,

BUREAU OF ENTOMOLOGY—BULLETIN No. 118.

L. O. HOWARD, Entomologist and Chief of Bureau.

THE BEAN THRIPS.

BY

H. M. RUSSELL,

Entomological Assistant.

ISSUED OCTOBER 16, 1912.



WASHINGTON:
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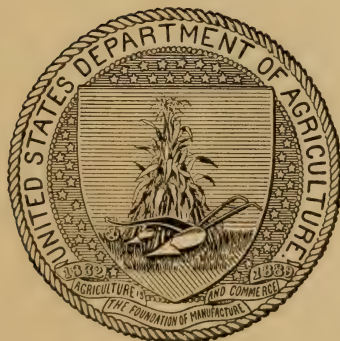
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LETTER OF TRANSMITTAL.

U. S. DEPARTMENT OF AGRICULTURE,
BUREAU OF ENTOMOLOGY,
Washington, D. C., April 24, 1912.

SIR: I have the honor to transmit herewith for publication a manuscript entitled "The Bean Thrips," by H. M. Russell, an entomological assistant of this bureau.

This bulletin deals with an insect pest of the family Thripidæ, the study of which has been hitherto largely neglected, and which of recent years has attracted considerable attention from an economic standpoint, as the cause of immense losses in the Pacific coast regions and elsewhere to truck farmers. The insect is closely related to the tobacco thrips, as well as to the onion thrips, to which species are chargeable untold losses in the production of these two staples. Experiments to produce formulæ and devices with which successfully to combat this insect are being perfected, and methods for the complete control of the pest are early expected.

I recommend the publication of this manuscript as Bulletin No. 118 of this bureau.

Respectfully,

L. O. HOWARD,
Chief of Bureau.

HON. JAMES WILSON,
Secretary of Agriculture.

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THE BEAN THIRPS.

(*Heliothrips fasciatus* Pergande.)

INTRODUCTION.

In the State of California during the past four or five years the bean thrips has been reported with increasing frequency as a serious pest to various crops. The common name "bean thrips" is somewhat of a misnomer, as this insect feeds on many different crops, but is retained here, as it is well known by that name in California. That State, with its long, dry summer, furnishes climatic conditions unusually favorable to the development of thrips, and several species have gained such a foothold there as annually to cause a loss of hundreds of thousands of dollars.

In the summer of 1909, Mr. R. S. Woglum, of the Bureau of Entomology, informed the author that during the summer before he had seen hundreds of acres of beans in southern California so seriously infested by the bean thrips that they had the appearance of plants scorched by fire; and as this thrips seemed to be increasing in numbers and destructiveness it appeared to be the part of wisdom to obtain all possible information concerning its life history and control before it reached the enormous abundance of the destructive pear thrips (*Euthrips pyri* Daniel). When, therefore, the Bureau of Entomology established a field station at Compton, Cal., in September, 1909, for the study of truck-crop and sugar-beet insects, the writer planned, among other projects, to undertake as complete a study of this insect as time would permit. With this in mind, the bean thrips has been the subject of thorough investigation during the years 1910 and 1911. During this time, however, the insect was not again so destructive to beans, so that remedies with spray mixtures could not be thoroughly tested. Nevertheless, as the life history has been worked out and a large fund of information obtained on the distribution and habits of this thrips, together with knowledge of a natural enemy of some promise, this paper is published at the present time.

At Compton, in Los Angeles County, where the life history of this insect was studied by the writer, the temperature is quite cool, since the location is near the coast.

In the Imperial Valley the life history of the bean thrips and its injuries to alfalfa and cotton have been investigated by Mr. V. L. Wildermuth, of this bureau, and where his observations are used credit is given in the text.¹ Use has been made of observations, by Messrs. P. R. Jones and S. W. Foster, of this bureau, on this insect in the more northern points in the State. Since July, 1911, the writer has been ably assisted by Mr. John E. Graf. He also wishes to express his appreciation to Dr. F. H. Chittenden, under whose directions he has conducted the investigation, and to Prof. F. M. Webster for the free use of notes obtained by his agents.

NATURE AND EXTENT OF INJURY.

The damage caused by the bean thrips is not confined to the foliage, but affects as well the fruit and stems of the plant attacked. The injury is caused by the method of feeding. Both young and adults obtain their food by puncturing the leaf tissue with their sharp mouthparts and, after lacerating it, withdrawing the plant juices at the point of attack. Figure 1, although a drawing of a different species, gives an idea of the mouthparts of this insect.



FIG. 1.—Side view of the head of a thrips, showing the mouthparts. Much enlarged. (After Moulton.)

Each time as the contents of the leaf at the point attacked are removed, the thrips moves to a new point and repeats the operation, so that if the insects are abundant or the attack is long continued the leaf tissue is destroyed over the entire surface. As the supply on one side of the leaf is exhausted the larvæ move around to the other, or if adults are present these fly or jump to more tender leaves. The infested and badly injured leaves turn yellowish or white, dry up, and either drop off or hang lifeless to the plant. Then, as the attack continues, successive leaves are attacked until in extreme cases the entire plant is killed.

DESCRIPTION.

Heliothrips fasciatus belongs to the Suborder Terebrantia and the Family Thripidae of the Order Thysanoptera, being placed in this position because of the downward-curved ovipositor of the female. The 8-segmented antennæ, with the last segment much longer than the 7th, and the reticulated surface of the body, together with the pointed spines on the wings, place this insect in the Genus *Helio-*

¹ Mr. Wildermuth studied the insect in its relation to alfalfa, without knowing that it was being investigated by the author. His studies, made under quite different climatic conditions, add materially to the value of the results obtained.

thrips. The habits of the larva are also quite characteristic of this genus, for the habits of the larvæ of the greenhouse thrips (*Heliothrips hæmorrhoidalis* Bouché) and of *Heliothrips rubrocinctus* Giard are almost identical with those of the present species.

THE ADULT FEMALE.

The adult female (fig. 2) is about one-twenty-fourth of an inch in length (0.9815 mm. to 1.1174 mm.; average, 1.0405 mm.) and about one-fourth as wide as long (0.2265 mm. to 0.2869 mm.; average

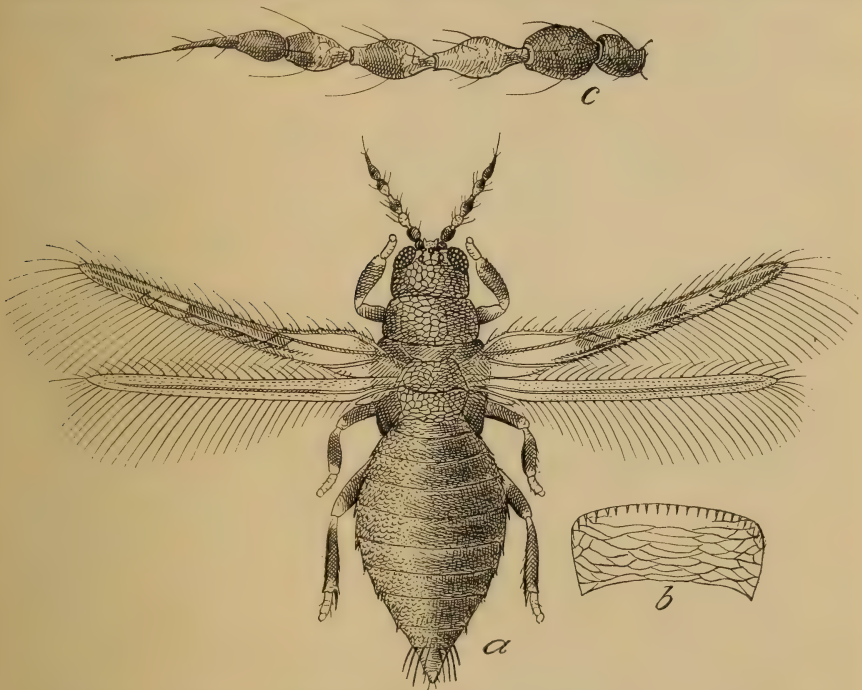


FIG. 2.—The bean thrips (*Heliothrips fasciatus*): *a*, Adult female; *b*, ventral side of abdominal segment of same; *c*, antenna of same. *a*, Greatly enlarged; *b*, *c*, more enlarged. (Original.)

width, 0.2529 mm.) and is fusiform in shape. The head and body are black and, under the microscope, are seen to be covered with distinct reticulations and short white hairs. The antennæ are 8-segmented and two and one-half times as long as the head, and are held out in front of the body. They are black, more or less banded with white, and bear white hairs. The wings are held folded together down the middle of the dorsum; they are black, crossed by a white band at the base and a white band at three-fourths the distance from the base. The wings are fringed with long white hairs. The legs are black, banded with white.¹

¹ For a detailed description of the genus and the species for use of systematists, see Hinds's "Monograph of the Thysanoptera" (Proc. U. S. Nat. Mus., vol. 26, 1902), pp. 174-175.

THE ADULT MALE.

The male resembles to a great extent the female, as the color and the markings are the same, but it is noticeably smaller in size and apparently more active. When viewed under the microscope the sexual organs are seen to be distinctly different, and in light-colored or cleared specimens the testes may be seen as two orange-red bodies in the abdomen, and on the middle of each of segments 2 to 6 on the ventral side are yellowish oval spots. The total length of the male is 0.7097 mm. to 0.8002 mm.; the average, 0.7474 mm. The greatest width across the mesothorax is 0.1963 mm. to 0.2114 mm.; the average, 0.1978 mm.

RECENTLY EMERGED ADULTS.

Both sexes, when just emerged, have the head and thorax a light yellowish orange, with the eyes and ocelli bright red. The antennæ are white and ringed with brown, while the wings are dusky, crossed by bands of a darker color. The legs are white, with ends of each segment more or less black. Gradually the color darkens, and in a day they all have the fully matured colors, as described above.



FIG. 3.—The bean thrips:
Eggs. Greatly enlarged.
(Original.)

THE EGG.

The egg (fig. 3) is bean shaped, 0.21 to 0.255 mm. in length and 0.105 to 0.12 mm. in width, and is very delicate and thin shelled.

It is translucent white, with a smooth shining surface. The eggs are laid in the tissue of the leaf or in the veins, or even in the stems, and in case of beans may be laid in the pods themselves. As the embryo within develops, the egg becomes swollen, and the little pocket in which it is inserted becomes raised above the leaf surface. The eggs may be seen in the leaf tissue if examined with a hand lens before the light. Each little egg pocket stands out, because of its lighter color, and within the crude outline of the egg may be seen.

The younger stages of this insect differ distinctly from those of *Heliothrips hæmorrhoidalis*¹ in the dashes of crimson so generally present on the sides.

THE FIRST-STAGE LARVA.²

(Fig. 4.)

Length, 0.42 mm.; width of mesothorax, 0.135 mm. General shape fusiform, similar to *Heliothrips hæmorrhoidalis*; head, antennæ, and legs large in propor-

¹ For description of *Heliothrips hæmorrhoidalis*, see "The Greenhouse Thrips," Bul. 64, Part VI, Bur. Ent., U. S. Dept. Agr., pp. 46-48, 1909.

² Description made while larva was very young and before feeding commenced.

tion to rest of the body. Color translucent white. Head large, quadrate; eyes reddish; ocelli absent. Antennæ 0.195 mm. in length, apparently 7-segmented; basal segment cylindrical, short; second nearly twice as long as first, barrel-shaped; third and fourth spindle-shaped, ringed with a few fine hairs; fifth, sixth, and seventh slender, nearly equal in length. Legs translucent white. Abdomen tapering posteriorly; first eight segments nearly equal in length, last two segments longer than others; each abdominal segment with longitudinal rows of setæ, the tenth with four setæ about 0.045 mm. in length.

At this stage there seems to be nothing to distinguish this species from *H. hamorrhoidalis*.

THE SECOND-STAGE LARVA.

(Fig. 5.)

Length, 1.05 mm.; width of mesothorax, 0.27 mm. Shape fusiform, about same as larva; of mesothorax and metathorax long, robust, cylindrical; sides of mesothorax and metathorax and first five abdominal segments nearly parallel; prothorax narrowed toward head; last five abdominal segments tapering to the last segment, which is cylindrical and truncated at end. Color of head and prothorax light yellow, mesothorax and metathorax and first six segments of abdomen translucent white, stained on sides with crimson blotches and with yellow on dorsum to some extent; next three segments of abdomen the color of head, last segment of abdomen white; alimentary tract plainly indicated by the brownish color



FIG. 4.—The bean thrips: First-stage larva. Greatly enlarged. (Original.)

given it by inclosed food. Surface of body covered with minute granulations. Head quadrate, rounded in front and notched behind the eyes, 0.12 mm. long, 0.0825 mm. wide; eyes small, reddish; ocelli absent. Antennæ 7-segmented, first four segments the color of head, the others translucent white; first segment short, cylindrical; second longer, barrel-shaped; third and fourth spindle-shaped and annulated; fifth, sixth, and seventh slender and cylindrical. Legs long, yellowish. Abdomen 0.60 mm. in length, fusiform, ovipositor not formed; segments with rows of fine setæ increasing in length toward posterior end; ninth and tenth segments with longer setæ.

THE YOUNG NYMPH OR PREPUPA.

(Fig. 6.)

Length, 1.02 mm.; width of mesothorax, 0.255 mm. Shape fusiform, similar to adult. Head, length, 0.09 mm.; width at eyes, 0.157 mm. Head translucent white, vertex slightly yellowish, ocelli absent. Head rounded in front, slightly notched behind the eyes; eyes red, made up of a few facets, surface faintly reticulated; two pairs of setæ behind the eyes and two pairs between the eyes. Antennæ translucent white, extending forward, 0.195 mm. in length; segments indistinct but apparently 7-segmented.

Prothorax about one-half again as wide as long, sides rounded, posterior edge broadest, semitranslucent white to yellow, posterior angles tinted with crimson.



FIG. 5.—The bean thrips: Second-stage larva. Greatly enlarged. (Original.)



FIG. 6.—The bean thrips: Prepupa. Greatly enlarged. (Original.)

setæ around margin. Mesothorax with rounded angles, translucent white to faint yellow, sides and posterior angles tinted with crimson, wing-cases transparent white, distinct from each other, those of forewings extending to middle of second abdominal segment and those of hind wings extending to middle of third abdominal segment. Legs strong, translucent white.

Abdomen fusiform as in adult, translucent white to faint yellowish, edges with tint of crimson, which enlarges to fair-sized blotches on sides of seventh and eighth segments; number of longitudinal rows of setæ increasing in length toward posterior end. Length of abdomen, 0.62 mm.

THE FULL-GROWN NYMPH OR PUPA.

(Fig. 7.)

Length, 0.99–1.09 mm.; width at mesothoracic angles, 0.24–0.255 mm. Shape similar to that of adult. Color orange; posterior border of prothorax, mesothoracic angles, sides, and abdominal segments 2, 3, 6, and 7 more or less crimson. Head, length, 0.11 mm.; width, 0.18 mm.; orange, apparently faintly reticulated; eyes dark red, larger than in prepupal stage, facets small. Three ocelli present in close triangle between eyes, in color yellow. Antennæ laid backward on head and reaching to beyond middle of prothorax; segments indistinct, translucent white; segments 1 and 2 projecting in front of the head and 2 with four setæ or hairs, two extending forward, about 0.0135 mm. in length. Thorax light orange or yellow. Prothorax about twice as wide as long. Wing-cases 0.54 mm. long, extending to seventh abdominal segment, translucent white. Length from head to end of wing-pads, 0.825 mm. Legs translucent white. Abdomen fusiform, similar to adult, surface plainly reticulated in older specimens, setæ well developed, the longest ones at posterior end. Length of abdomen, 0.612 mm.; width, 0.31 mm.; length of posterior setæ, 0.085 mm.

The younger stages of this insect differ distinctly from those of *H. hæmorrhoidalis*¹ in the dashes of crimson so generally present on the sides.

The pupa of the male is shorter and more slender than that of the female. This pupa differs

from *H. hæmorrhoidalis* in its smaller size, in its yellow color, with the sides of the abdomen more or less stained with crimson, and in having the hairs of the body longer and the second segment of the antennæ with two long setæ.

The foregoing descriptions are for the parts of California in Los Angeles County and more northern points, for Mr. Wildermuth



FIG. 7.—The bean thrips: Pupa. Greatly enlarged. (Original.)

¹ For description of *Heliothrips hæmorrhoidalis*, see "The Greenhouse Thrips," Bul. 64, Part VI, Bur. Ent., U. S. Dept. Agr., pp. 46–48, 1909.

found that the different stages in the Imperial Valley lacked the red markings except in the cooler weather of the late fall.

ORIGIN AND DISTRIBUTION.

This insect was first described by Mr. Theodore Pergande from specimens taken in Yuba County, Cal. A few years later he identified a thrips from Lewiston, Idaho, as this same species.

Mr. Dudley Moulton reported that this species had been collected in Colusa County by Mr. E. K. Carnes, in Santa Rosa County by Mr. O. E. Bremner, and in the Santa Cruz Mountains, Santa Clara County, by himself. Mr. D. L. Crawford recorded *fasciatus* from Santa Paula, Ventura County, Cal., and from Claremont and Chino, Cal. Mr. William B. Parker, of this bureau, collected it at Davis and Hamilton City, Cal. Mr. P. R. Jones, engaged in pear thrips investigations, reports that this insect occurs very commonly around Lindsay and San Jose, Cal. Mr. S. W. Foster, while engaged in the same investigation, collected this insect from Martinez, Cal., and later found it "frequently throughout Contra Costa County."

Mr. V. L. Wildermuth, engaged in cereal and forage insect investigations, has collected this insect in California at Indio, Riverside County, and at Bard, El Centro, and Holtville, Imperial County, and in Arizona at Yuma, Yuma County, Buckeye and Tempe, Maricopa County, and Sacaton, Pinal County.

During the present investigation the writer has collected this insect quite extensively from many places in southern California. In 1910 it was found to be very abundant on wild lettuce in several yards and alleys in the city of Los Angeles itself. At various times it has been collected from Bell, Compton, Gardena, Glendale, Hollywood, Laurel Canyon, Puente, San Gabriel, Sierra Madre, Tropic, and Whittier, in Los Angeles County. In Laurel Canyon the author found it feeding on wild food plants in uncleared land about 6 miles from cultivated fields. It was also collected near the entrance of the canyon, scattered over the mountain sides on various wild plants. At Sierra Madre it was taken at an elevation of 750 feet.

It was also collected at Garden Grove, Huntington Beach, Smelter, and Sunset Beach, in Orange County, Cal. While on a trip in October, 1910, the author found this insect to be generally distributed throughout the town of Oxnard, and in Montalvo and the entire outlying sugar-beet district of Ventura County.

In February, 1911, the author made a trip to San Diego to investigate the conditions in reference to truck crops there, and in Mission Valley—a long, narrow, and fertile valley lying to the north of San Diego, and devoted to truck crops—this insect was found feeding to some extent on pea vines. The writer left California for Washington, D. C., in September, 1911, and while delayed at Sparks, Nev., he examined several clumps of wild lettuce growing along the rail-

road track and collected both larval and adult forms of the bean thrips upon this plant.

Mr. A. C. Morgan, of this bureau, recently reported to the writer that he had collected the species on October 10, 1910, at Clarksville, Tenn. The fact that this insect is so widely distributed in all parts of California seems to point strongly to that State as its original home. This is also strongly supported by the fact that Moulton collected it from wild vetch in the Santa Cruz Mountains and that the writer collected it in wild, uncultivated tracts in the mountains and canyons north of Los Angeles, 5 and 6 miles from cultivated crops. This point of view is further strengthened, because the author has found this insect feeding on more than 20 native wild plants.

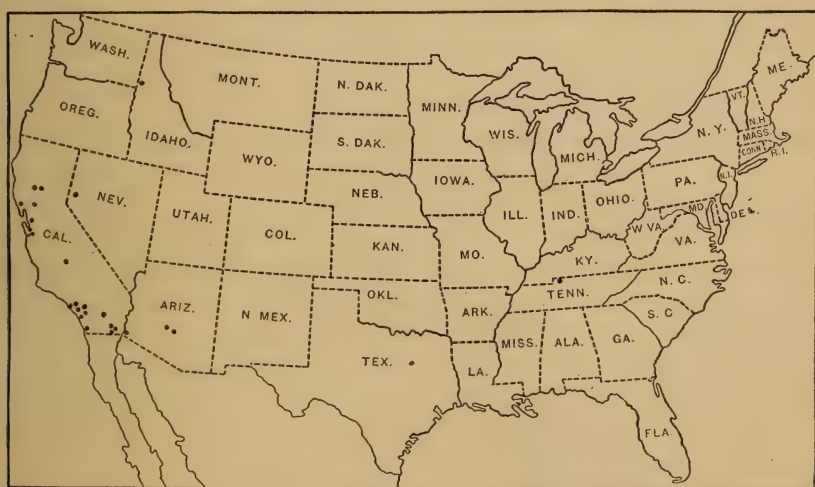


FIG. 8.—Map showing present known distribution of the bean thrips (*Heliothrips fasciatus*). (Original.)

Mr. J. D. Hood, formerly of the office of the State entomologist of Illinois, recently informed the writer that he possessed specimens of this thrips that were collected by Prof. Lawrence Bruner at Lincoln, Nebr., February 14, 1899, and that he had collected this same species at Urbana, Ill., in March, 1907. In both cases the thrips were taken on California oranges and had evidently been carried across the country while hibernating in the navel end of the fruit. This is an excellent illustration of how this insect may be distributed through the agency of man.

Although this insect is quite minute and has been little studied, at the present time it is known to occur through the entire State of California, in several places in Arizona, in Nevada, and in Idaho near the Washington State line. It has also been found in one locality in Tennessee. Figure 8 has been prepared to show the present definite localities where this insect has been observed.

Without doubt this insect occurs over the entire Pacific coast of the United States and down into Mexico for some distance and possibly even into Central America. As it becomes better known it will probably be found to occur in several of the other Western States and some of the Eastern States as well.

HISTORY.

In 1895 Mr. Theodore Pergande (1)¹ described this species from one specimen received from Yuba County, Cal., where it was taken on an orange leaf infested with (*Aspidiotus*) *Chrysomphalus aurantii* Mask. At that time he expressed the opinion that the occurrence on this plant was accidental. In view of our present knowledge, however, of the feeding habits of this insect, this specimen was probably feeding on the foliage of the orange itself.

In 1902 Hinds (3) redescribed the female from one specimen in the collection of the Bureau of Entomology. At that time he wrote that nothing was known of the life history.

Miss Daniels (4), writing in 1904, noted the occurrence of this thrips in California. At the same time she erected a new genus and species, *Caliothrips woodworthi* (4), for the male of *Heliothrips fasciatus*. This error was first pointed out by Dudley Moulton (6) in 1907, and the present writer agrees with him, as the male of *fasciatus* fits the description exactly except in the number of antennal segments. Undoubtedly Miss Daniels made a mistake in the number of segments in the antenna, since *fasciatus* is 8-segmented only.

Crawford (7), in 1909, under "Notes on California Thysanoptera," records taking numerous specimens in southern California. These were captured on pine, *Lotus glaber*, and apple.

Under the name *Euthrips fasciatus*, Bremner (8), in 1910, reported this insect as injuring beans and peas and as occurring on alfalfa and on peach and pear trees. He recommended spraying with nicotine solutions, and wrote that of these sulphate of nicotine in the proportion of 1 ounce to 5 gallons of water had given perfect success.

In 1911 Coit and Packard (9) wrote that the bean thrips caused considerable defoliation to cotton and alfalfa in Imperial Valley, Cal. Moulton (10) also gave a list of its food plants.

The present writer, in 1911 (12) and also in 1912 (13), published two papers dealing with the life history and habits of *Thripoctenus russelli* Crawf., a parasite reared in large numbers from this thrips.

RECENT RECORDS.

This species, as identified by Mr. Pergande, was sent to the Bureau of Entomology January 25, 1898, by Mr. M. J. Wessels, of Lewiston,

¹ Numbers in parentheses refer to the Bibliography, pp. 44-45.

Idaho, who collected it in a diseased spot of a crab apple. On August 27, 1908, Mr. I. J. Condit sent in specimens of this thrips from Davis, Cal., where they were injuring sugar beets. He wrote:

I examined the beets and found them literally covered with thrips, both the surface and underside of the leaves being badly infested. There were very few leaves which were not attacked, most of them having the appearance of the specimens sent. A field of tomatoes near by was also becoming infested. The lower leaves especially were yellow and some falling off.

Mr. S. W. Foster informed the writer that on August 26, 1909, Mr. Frank T. Swett, of Martinez, Cal., sent to the laboratory of the Bureau of Entomology at Walnut Creek, Cal., a quantity of pear leaves badly injured by this species. On August 31 Mr. Foster visited the orchard and found the injury quite noticeable. He wrote that "the foliage gave the appearance from a distance of having been scalded." Mr. V. L. Wildermuth, of this bureau, sent specimens taken on alfalfa at Indio, Cal., on July 2, 1910. Mr. A. McLachlan, of Davis, Cal., sent in specimens of this thrips on October 13, 1910, with the report that they were injuring the buds and tips of cotton.

Mr. W. B. Parker, of this bureau, under date of August 25, 1911, sent this insect from Davis, Cal., with the statement that it was causing serious damage to the foilage of the sugar beet. He also collected it on sugar beets at Hamilton City, Cal., on September 18, 1911, where it was causing some injury. He wrote, however, that owing to the lateness of the season when the beets were attacked probably only slight damage resulted.

HABITS OF THE ADULT.

For a short time after emerging from the pupa this insect remains quiet and appears to be waiting for its limbs to harden. During this time the colors, which were light at emergence, gradually darken. After hardening the thrips moves off and begins feeding.

METHOD OF MATING.

The males and females of this species seem to emerge from the pupa at about the same time. During this investigation it was observed that, under laboratory conditions at least, the sexes mated generally in from two to three days after emergence and in some cases in even less time. This operation has been observed both in the field and in the laboratory and was identical under both conditions. This is probably best described by the original field notes made at the time of observation.

The male,¹ when inclined to copulate, picks out a female, and if she is moving over the leaf runs after her and jumps or alights on her back. In some cases he then spreads the wings and moves them up and down, at the same time moving the tip of the abdomen in the same manner. In other cases the male, after leaping onto the back of the female, remains motionless for some time in that position. It then exserts the copulatory organs from the tip of the abdomen and shifts around toward the side of the female, at the same time bending the abdomen under to the ventral side of that of the female. The copulating organs are then moved back and forth until they encounter those of the female. In some cases observed, when the male did not succeed in connection, it would withdraw to its former position on the female and after remaining quiet for a short time would move over and attempt the act on the opposite side. As soon as connection is made the male remains motionless for a short time, during which period the female, in many cases, crawls slowly around on the leaf. After a few minutes the male relinquishes his hold with the copulating organs and moves squarely back onto the dorsum of the female. Soon after the male crawls off and away from the female. This entire operation was observed in three cases to occupy 3, 5, and 10 minutes. Several cases were observed where two males attempted copulation with the same female, but, after a vain attempt, one generally left her.

METHOD AND TIME OF OVIPOSITION.

Exactly how much time elapses between copulation and oviposition was not observed, but probably not more than a day, so that the female will begin oviposition within three days from the time she emerges from the pupa. In one case adults emerged on July 19, 1911, and eggs were laid four days later.

Oviposition usually takes place during the night, but has been observed at 2, 3, and 4.30 in the afternoon. A female engaged in oviposition was observed to crawl over the leaf of the food plant for a short distance and then to stop and scrape a hole in the leaf with her mouth cone. This was accomplished by a slight forward and backward motion like that of a chisel. In a short time the female ceased this action and moving forward until she could place the tip of the abdomen where the tissue had been ruptured, arched the abdomen in the middle, and brought the tip to the opening in

¹ Pietro Buffa (Atti Soc. Toscano Soc. Nat. Mem., vol. 23, p. 48, 1907) figures *Æolothrips fasciatus*, female and male in copulation, in a position identical with that observed by the writer in *Heliothrips fasciatus* on many different occasions.

A. F. Shull (A Biological Survey of the Sand Dune Region of Saginaw Bay, Mich., pp. 190-192), describing copulation in the suborder Terebrantia, expresses doubt as to the position of the male on the back of the female during copulation. As his observations on *Euthrips tritici* were made under unfavorable conditions his conclusions were probably erroneous.

the leaf surface. She then proceeded to work the ovipositor back and forth in the rupture until she had made an incision of sufficient depth. After this she became motionless for a varying length of time, while the egg was being deposited, whereupon the ovipositor was removed, and the female moved away.

A number of cases have been observed where the female, after inserting the ovipositor, could not withdraw it, and, thus held, she soon died.

NUMBER OF EGGS AND PERIOD OF OVIPOSITION.

Owing to the artificial means used in studying the habits of this insect it was impossible to determine exactly how many eggs a female is capable of laying. However, the writer confined 6 females in a vial for observation. They laid an average of 35.5 eggs each, while the highest average for any day was 5.5 eggs each. Another female, during the period from August 16 to August 23, 1911, laid 16 eggs, the greatest number laid in any one day being 5. At Compton, Cal., during 1911, females kept in confinement were observed to oviposit for 30 days in succession, while others were observed to oviposit 51 and 83 days after they emerged from the pupæ. If this insect normally continues oviposition regularly over a period of 83 days the total number of eggs laid must be very large.

Mr. V. L. Wildermuth, while in the Imperial Valley, made some interesting notes on the number of eggs this species may deposit. On August 2, 1910, he confined 2 females on leaves of alfalfa in a vial, and on August 5 these leaves contained 50 eggs, or an average of 25 eggs each in 3 days. His other observations are given in Table I.

TABLE I.—Number of eggs deposited by the bean thrips (*Heliethrips fasciatus*), Imperial Valley, Cal., 1910.

Experiment No.	Date female was put in vial.	Date and number of eggs.							Total period of oviposition.	Total number of eggs.
		1910.	Eggs.	1910.	Eggs.	1910.	Eggs.	Dead.		
	1910.								Days.	
1	Aug. 29.....	Sept. 1	36	Sept. 2	6	Sept. 6	37	○	7	79
2	Aug. 31.....	Sept. 4	42					○	3	42
3	do.....	Sept. 7	53					○	6	53
4	do.....	Sept. 1	20					+	1	20
	1911.									
5	Sept. 23 ¹	Sept. 30	12	Oct. 3	25	Oct. 11	24		46	134
				Oct. 21	47					
				Nov. 1	27	Nov. 11	11			

¹ Record made at Tempe, Ariz.

In these experiments the longest period of oviposition was 46 days, and the largest number of eggs laid by a single female, 134.

It will be observed from these figures that the females observed by Mr. Wildermuth deposited more eggs and at a more rapid daily rate

than those observed by the writer. This may have been due to the higher temperature of the Imperial Valley and vicinity, where his observations were made. Mr. Wildermuth noted adults in copulation the day that they emerged, and oviposition on the following date. He also observed this species to oviposit during the entire day, whereas the writer never observed it to oviposit except in the afternoon or night.

PROPORTION OF THE SEXES.

The bean thrips was under the observation of the writer for a period of more than two years, during which time it had been observed in the field at all times of the year. In all observations made during the investigation of this insect the males and females were collected together and copulation was observed from early in February until reproduction ceased late in the fall. Apparently the females outnumber the males, but this may be due to the fact that the females are not quite so active as the males, and are not disturbed on the plants when examined. On June 9, 1911, out of 17 specimens reared in the laboratory 9 were females and 8 males. July 17, 1911, the writer examined another series of live adults that were reared in the laboratory. Out of 106, 80 were females and 26 males. A third series of reared adults was examined October 16, 1911, and out of 44 adults 32 were females and 12 males. Apparently the percentage of females is too high and does not indicate the exact relation between the sexes.

KINDS OF REPRODUCTION.

In all observations made on this topic reproduction has been bisexual, and in view of the fact that males were observed at all times and copulation also occurred at all times in the year when this insect was active, this would seem to be the usual method. However, although the few experiments made to determine whether parthenogenesis occurred gave negative results, in view of the preponderance of females during certain parts of the season it is quite probable that asexual reproduction may occur. It would seem that this method would occur under certain conditions, especially in view of the fact that the greenhouse thrips (*Heliothrips hæmorrhoidalis*)¹ reproduces, so far as we know, asexually only, the male having never been discovered.

FEEDING HABITS.

Both the adult and larva of this thrips injure the host by feeding on the foliage. As in the case of the greenhouse thrips, the lower

¹ "The Greenhouse Thrips," Bul. 64, Bur. Ent., U. S. Dept. Agr.

and earlier leaves are first attacked in the spring by the adults. These feed on the underside of the leaves, scraping out the leaf content in small spots that become white and conspicuous. Often the adults move along and leave a chain of white spots to mark their progress. The adults also feed to some extent on the surface. As they feed the females deposit their eggs in the leaf tissues, and as soon as incubation is completed the larvæ hatch and join the adults on the leaves. Under these conditions the leaves become more or less dried and lifeless, and the adults move to the higher and more tender leaves of the plant. In this way the entire plant may become infested. On February 5, 1911, the writer found the adults of this insect extremely abundant in the pea field of some Chinese truckers at Hollywood, Cal. Here nearly every plant had 7 or 8 adults feeding on the underside of the foliage, and in many cases 5 and 6 were present on each leaf. On August 18 of the same year in the same locality plants of spiny wild lettuce (*Lactuca scariola*) were observed that had 50 adults feeding on a single leaf.

The adults seem to feed on a large variety of plants and have been found feeding on all of the plants given under "List of food plants." It may be well to state at this point that the presence of adults on a plant has not been considered sufficient evidence to class that plant as a food plant, but whenever larvæ of this insect were taken on a plant, this was considered sufficient to rank the plant as a host.

In the spring when the adults leave hibernation they collect on the wild food plants present and feed on them until their injury, due to an increase in numbers and feeding, weakens the plants and shortens the food supply; then they fly to fresh plants of the same hosts or to cultivated crops and fruit trees nearby. Of all the food plants observed, the spiny wild lettuce (*Lactuca scariola*) seems to be the most favored. This plant has been found to be infested more heavily than any of the other food plants concerned, not excepting those of economic importance.

FLIGHT.

The present writer in his investigations of the greenhouse thrips¹ never observed that insect to take flight naturally, or even when disturbed. The adults of *Heliothrips fasciatus*, on the contrary, take flight very readily, and if jarred or disturbed will usually fly or jump. This species in taking flight raises the tip of the abdomen quickly, and separates the wings. It then rises straight up into the air and flies rapidly away in short undulating curves. Indeed, to the untrained eye it appears, in flight, exactly like a small speck of soot being blown around by a slight breeze. This power of flight aids greatly in the dispersion of this insect during the spring and summer.

¹ Loc. cit.

LEAPING.

This species possesses the power to leap actively and, considering its size, to a considerable distance. It is no uncommon occurrence for the specimens which are being examined upon a plant to leap off and be lost. Like the greenhouse thrips, it will crawl over the leaves rapidly when disturbed. At other times it will remain motionless for a considerable period, lying closely to the surface of the leaf along one of the veins.

NORMAL LENGTH OF LIFE.

The length of life of this insect as an adult has been determined under the artificial conditions of confinement in vials containing fresh leaves of the food plant. As often as these lost their freshness other leaves were put in and the adults were changed with a camel's-hair brush.

Even under these conditions the length of life observed for some individuals was surprisingly long, when we consider the minute size of the insect. During these experiments it was observed that these insects were very sensitive to humidity or a lack of it and all were soon killed whenever the vials used in confining them became too dry. Table II shows the results of these experiments in which some thrips lived for 84 days.

TABLE II.—*Length of life of adult bean thrips at Compton, Cal., 1911.*

Date adults emerged from pupa.	Number emerged.	Specimens died.		Last adult died.	Maximum length of life.
		Date.	Number.		
April 16.....	3	{ May 8	1	{ May 22	37
		{ May 11	1		
April 23.....	11	{ May 8	12	{ July 14 ³	84
		{ May 18	1		
		{ May 26	1		
		{ June 5	1		
June 5.....	9	{ June 17	5	{ Aug. 14	71
		{ June 21	3		
		{ July 22	2		
July 19.....	14	{ July 25	2	{ Aug. 21	34
		{ July 26	2		
		{ Aug. 8	2		
		{ Aug. 12	2		
		{ Aug. 17	1		

¹ Dead.² Lost.³ Male and female.

LENGTH OF LIFE IN WINTER.

A number of adults were collected from host plants on November 18, 1910, and were placed in vials and furnished with fresh leaves at intervals, and some lived in confinement in this manner until February 1, 1911, by which time all had died. On January 16, 1911, a num-

ber of adults were taken from the open on leaves of nasturtium and were placed in vials. These died in April, giving a length of life after being collected of 92 days. As adults have never been observed to emerge from pupæ later than December 27, these adults must have been at least 21 days old when collected, so that they lived about 113 days. Probably hibernating individuals live as long as 5 months.

HABITS OF THE LARVA.

In observing the habits of the larva of this thrips, the writer was constantly impressed with the great similarity that existed between this species and the greenhouse thrips. This is so great that the description of habits of the one would almost equally fit the other.

HATCHING.

Apparently the hatching process may occur at any time during the day. Many have been observed hatching early in the morning and one larva was observed emerging from the egg cavity at 4.25 p. m. Very slowly this larva pushed its way out of the egg cavity,¹ during which time the appendages were all held closely appressed to the body and were invisible. As soon as the body was nearly out the insect began a slow forward and backward movement and at 4.40 p. m. all but the tip of the abdomen was free, while the larva projected straight out from the leaf surface. While held in this position it began slowly to unfold the limbs and antennæ and move them around. The motion was very feeble at first, but gradually the larva seemed to gain strength and at 4.48 p. m. it bent over and, grasping the leaf surface, began to pull with its limbs in order to free itself. This was accomplished at 4.53 p. m., making the total period required in emerging from the egg 28 minutes.

The larvæ of this insect after hatching move away a short distance, then appear to rest for a few minutes until they become stronger. Within a short time, however, they move on and soon commence feeding. When first hatched the larvæ are very minute and almost colorless, but as they begin to feed and drain the green coloring matter from the leaf the alimentary tract becomes plainly visible from the contained food. In a few days the color of the body becomes more or less yellowish and blotched with crimson. In common with other species of Heliothrips, the larvæ of the present species keep the tip of the abdomen elevated and carry around on it a small globule of reddish liquid excrement. Gradually this globule increases in size until it is too large to be carried any longer and it falls to the leaf surface. Here in time it dries and forms a black spot or scale. The occurrence of these spots on the leaf of a plant

¹ This larva emerges from the egg by the same method that is used by the conchuela (*Pentatoma ligata* Say) as described by Morrill (Bul. 86, Bur. Ent., U. S. Dept. Agr., pp. 38-39).

marked by feeding of some thrips furnishes good evidence that the bean thrips has been feeding there at some time. The larvæ feed in much the same manner as the adult, the mouthparts being practically the same. They gradually scrape out the contents of the leaf, leaving silvery spots, which as they become abundant often unite and gradually destroy the vitality of the leaf. Most of the eggs seem to be laid on the underside of the leaves, although the writer has observed eggs to hatch from the upper side also. As a consequence the larvæ begin feeding largely on the underside of the leaves. After hatching they do not move far before commencing to feed, during which time, under ordinary conditions, they move very little. When plants are first infested the larvæ seem to feed close to the leaf veins, but as they become more abundant they scatter in groups over the entire leaf surface. Like those of the greenhouse thrips the larvæ of this species seem to cluster in colonies and unless disturbed, or in need of fresh food, remain thus. The colonies are in many cases found in between two veins of the leaves. When disturbed the larvæ will violently twitch the end of the abdomen with its drop of liquid and move away rapidly. Apparently this is used as a means of defense, for the writer, in work with a parasite of this thrips, observed at times that these larvæ when touched from in front by the parasite flung the abdomen around and moved rapidly away. When this occurred the parasite generally retreated, but returned to the attack and later usually succeeded in ovipositing in its host.

The larvæ and adults of this thrips feed together in colonies, and as the leaves become crowded or dry from excessive feeding the larvæ move in search of fresh food. Gradually the whole underside of the leaf attacked becomes infested by the larvæ and then the surface as well. In fact, the writer has seen leaves so heavily infested by the larvæ of this thrips as to give them a decidedly reddish color, due to the bodies of the insects. So far this larva has not been observed feeding in the blossoms of any plant, but in some cases it has been observed feeding on green tomatoes, and when bean vines are badly infested the pods are also attacked. Indeed, when excessively abundant, these insects will not only cover both sides of the leaves, but the stem of the plant as well. The larvæ as a rule feed unprotected on the leaf, but at times may be found feeding under the protection of red-spider webs.

Apparently these minute creatures are not affected by dust, as the writer has found them feeding in large numbers on leaves of spiny lettuce in an alley in the city of Los Angeles when the leaves were so thickly covered with dust as completely to hide the surface. It would seem that with the enormous clouds of dust that arise in this section during the entire summer, completely coating the larvæ, they would speedily succumb.

As an illustration of how abundant this insect may become, the following observations are given: On August 31, 1909, Mr. Foster, of this bureau, found it severely infesting pear foliage at Martinez, Cal., and noted as many as 200 larvæ on one side of a leaf. On July 28, 1910, the writer found some plants of spiny lettuce badly infested by the larvæ of this thrips, and 10 leaves gave a total infestation of 733. (See Table III.) This gave an average of 73.3 to each leaf.

TABLE III.—*Infestation of Lactuca scariola by larvæ of the bean thrips.*

No. of leaf.	Number of larvæ on under side.	Number of larvæ on upper side.	Total number of larvæ on leaf.	No. of leaf.	Number of larvæ on under side.	Number of larvæ on upper side.	Total number of larvæ on leaf.
1	70	7	77	7	44	47	91
2	34	39	73	8	61	30	91
3	43	2	45	9	70	1	71
4	30	2	32	10	23	32	55
5	59	47	106				
6	46	46	92		480	253	733

On July 18, 1911, at Hollywood, Cal., leaves of spiny lettuce were found that had several hundred larvæ to a leaf. September 22, 1910, Mr. Wildermuth observed a field of cotton at El Centro, Cal., showing considerable injury by this insect, and counted as many as 200 larvæ to a single leaf.

MOLTING.

The larva molts once, giving two larval instars, then molts to the prepupal stage. On July 28, 1910, a number of larvæ that had just hatched were separated and on August 2 these all molted. On August 7 they again molted and changed to prepupæ. This gave the first instar a length of five days and the second a length of five days. The process of molting in the larva is continued unprotected in the midst of the feeding colony. After molting the skin is left adhering to the leaf beside the feeding larva.

It was observed with the larvæ of this species and of those of the greenhouse thrips that when they were exposed to a low temperature the entire development was checked and growth remained stationary during the exposure. In long-continued exposures the insects were killed, but if within three weeks they were again removed to higher temperatures the larvæ resumed their growth and pupated in a few days.

Under the artificial conditions of rearing in vials the mature larvæ seek concealment before pupation in curled-up leaves, in all kinds of protected places, and if in vials closed with cotton plugs they work their way in between the plug and side of the vial. In the field, however, the larvæ when full grown desert the plants and hide in rubbish and cracks in the ground or beneath clods of earth.

The molting from larva to prepupa under laboratory conditions has been observed many times. On April 10, 1911, a mature larva was observed to begin the process at 4.05 in the afternoon. After remaining motionless for some time it arched its body, and shortly after the skin split down the head behind the antennæ. The head gradually forced its way out of the opening, then the body followed, the old skin being slipped off behind. This molting was completed at 4.21 p. m.

HABITS OF THE PREPUPA AND PUPA.

The prepupæ of this insect are found in company with the pupæ and full-grown larvæ in small social colonies. These hold the antennæ out in front of the body and move about to some extent. The pupæ, however, carry the antennæ folded back on the head and thorax and remain motionless unless disturbed or exposed to the light, in which cases they will slowly crawl away. When compelled to pupate in closed vials the prepupæ and pupæ occur in large numbers closely packed together along the edge of the vial and the cotton plug or buried in the cotton itself. In nature it has quite different habits. While the greenhouse thrips under natural conditions pupates on the leaf of the food plant in among the feeding larvæ, with the bean thrips this seldom takes place, and during the two years this species has been under observation by the writer only three pupæ have been found on the plants infested by hundreds of thousands of larvæ. In one case a pupa was found under the web of the red spider near the midrib of a leaf of spiny lettuce; in another, one was found under a web of red spider on a leaf of the wild tobacco flower; and the third was found in a curled-up lettuce leaf.

December 17, 1910, a quantity of the dead leaves of wild heliotrope were collected on the ground under infested plants. Prolonged sifting revealed the presence of a single pupa. In 1911, the prepupæ and pupæ were found by Mr. John E. Graf and the writer to be very abundant in infested bean fields under clods or lumps of dry earth and in cracks or holes in the lumps. Upon exposure to the light these at once began to move away in search of darkness.

Mr. Wildermuth also found the pupæ of this insect underground. He wrote in his notes on September 23:

While searching by aid of a binocular for pupæ, I found one pupa, one prepupa, and two (mature) larvæ just at the crown of the plant and beneath the soil; one pupa about one-fourth inch below the surface of the soil in an oval cavity about three times as long as the pupa itself; one prepupa between a dead leaf and the soil. Never have I found a pupa above the surface of the ground, on the leaves of the plant, or between the sheath leaves and the stem, as frequently occurs in confinement.

The molting of the prepupa to the pupal stage is very similar to that described for the change of the larva to the prepupa. It takes

place in whatever location the prepupa may be, and the transparent and delicate empty skin is found behind the pupa. It was observed during the fall that pupæ exposed to a low temperature did not complete their development to the adult stage. These, when later placed in the greenhouse, changed to adults unless exposed to the unfavorable conditions too long, when all were killed.

During the pupal stage several external changes take place. At first the ocelli are not evident, but as the pupa develops these become prominent in a triangle between the folded antennæ. Then the reticulations of the body begin to appear, and within two days of the emergence of the adult the pupa begins to darken and the legs, antennæ, and wings begin to show blackish bands. The adult emerges in a manner similar to the molting of the larva. Emergence has been noted at all hours of the day, and there seems to be no particular time for its occurrence.

FOOD PLANTS.

This insect seems to be nearly as omnivorous as the onion thrips, as the following list of food plants upon which it has been reared or observed during the past two years by the writer would indicate. These have been divided into economic and wild food plants, and under each will be given notes on injury and appearance of injured plants.

BEANS.

The injurious occurrence of this insect on the foliage of beans gives to it its common name. It has been observed by the writer to feed on bean foliage in the adult and larval stages from early in February, in sheltered places, until the plants are killed by frost in the fall. In the spring the wild plants are first up, and the attack is largely concentrated on them, so that when the beans come up they are not immediately attacked. However, in a few weeks the insect spreads to the beans, thereafter increasing in numbers until in the late summer and fall much injury is done. When snap beans are infested the adults first attack the leaves, and while feeding lay countless eggs in the tissue. The larvæ on hatching begin to feed, and gradually the green coloring matter is entirely removed from the underside of the leaf. This becomes white and covered with the black spots of excrement. The infestation then spreads to the surface and to other parts of the plant. As the feeding goes on the leaves lose all color, become white, or dry up and turn brown and drop off. As the infestation increases, the stems and pods themselves are also attacked and ruined. A badly infested field appears as if scorched by fire. The lima bean and pink bean suffer in the same way. The blackeye cowpeas this past season were almost immune from the attack of this insect, even in fields in which the pink beans and spiny lettuce were very badly infested.

OTHER VEGETABLES.

During the spring and early summer this insect is not noticeable on either the sugar or table beets. Late in the summer, however, as the wild plants die down, these plants often become badly infested, but as the beets have nearly completed their growth little real injury results. The outside leaves seem to be first infested, showing series of minute white spots more or less in chains, where the chlorophyll has been removed, but in badly infested leaves the underside becomes white and dried and covered with small black spots, causing the leaves to wilt. Mr. Parker wrote from Hamilton City, Cal., under date of September 18, 1911, that the injury was apparent in almost every field.

Cabbages and other crucifers are commonly infested by this thrips and at times may be seriously injured. On March 27, 1911, cabbages in the laboratory yard were slightly infested. Where they had fed long the underside of the leaf was full of the silvery-white feeding marks of this insect and the tiny black specks of excrement. Cauliflower suffers to the same extent as the less valuable cabbage.

This insect has also been found feeding quite extensively on lettuce, potato, and tomato. At Hollywood, Cal., in February, 1911, it was very abundant on the foliage of pea vines, but the infestation did not appear to increase, probably because the vines were quite old.

PEAR.

Mr. S. W. Foster found pear foliage badly injured on August 31, 1909, at Martinez, Cal. He wrote:

The foliage gave the appearance from a distance of having been scalded. Close examination showed that the leaves were often injured in large areas on either or both surfaces. The larvæ, feeding only on these outer surfaces, soon cause the blackened areas.

As the tree has made most of its growth for the season and the fruit crop has been harvested, it is hardly probable that this species will prove of serious consequence to the growers unless it should get so numerous as to appear in numbers early in the season.

ALFALFA.

The following field observations on the work of the bean thrips on alfalfa and cotton were made by Mr. Wildermuth in the Imperial Valley, Cal.:

August 2, 1910. This thrips does nearly all if not all of its feeding on the upper surface of the leaf. The excrement is arranged in definite rows, often semicircular in form, around these eaten spots and makes a very characteristic mark [see fig. 9]. The eaten spots later turn yellow and then the alfalfa presents a sickly appearance. August 4 I visited several alfalfa fields and all were very much injured by this thrips. Scarcely a leaf could be found that

was green and fresh as it should be. The fields examined have a whitish-yellow cast to the usual green appearance. August 30 several fields were visited and every leaf in the fields examined was attacked by the thrips. The alfalfa has a whitish and bleached appearance, due to the effects of the thrips' feeding. I never saw anything to equal this in appearance or in thoroughness



FIG. 9.—Alfalfa showing injury by the bean thrips. (Original.)

of attack. September 30 the fields were still being badly damaged. After a field is newly irrigated just after cutting for a week or 10 days the damage is not noticeable, but after three weeks nearly all leaves show the effects and the alfalfa presents a very sickly appearance. A lack of sufficient water causes the damage to be more noticeable, as under such a condition the growth of the alfalfa is not so rapid and the thrips' damage is more conspicuous.

On September 18, 1911, he wrote:

This thrips is very abundant in alfalfa fields at this time of year, the larvæ being present on the older alfalfa and the adults present on the younger shoots and leaves. Many leaves, after being badly scarred by the thrips, wilt and fall off, so that the damage is soon very great. It seems rather strange that this thrips should become so very abundant in the fall of the year and *Euthrips tritici*, the other important alfalfa thrips, should decrease in numbers and that in the spring of the year just the opposite should be the case.

COTTON.

September 22, 1910, Mr. Wildermuth wrote:

This thrips was found damaging cotton about 11 miles southeast of El Centro, Cal. The cotton was only damaged in one corner of the field, and it happens that fresh alfalfa is being stacked close to this corner.

September 28 a field of cotton east of Imperial had a strip through the center of the field damaged by this thrips. September 30 numerous fields on the east side of the valley were being damaged by this pest. The leaves were dead and rusty looking and the plants in bad condition. The damage was not as great as if the work had begun earlier in the season, but was at that time very great.

October 11 several cotton fields at Holtville, on the east side of the valley, were examined. A great many fields showed considerable injury. The leaves were eaten and turned a sickly yellowish or brown, many often being curled. A field on the Young ranch was as badly damaged as any seen, and this field lay alongside an alfalfa field. Three other fields on the same ranch showed very little damage. The former field was of a late planting. This thrips has caused much more damage to cotton than was anticipated, and if it should begin its work early in the season it might prove extremely destructive. Because of this, as well as other still better reasons, cotton should be planted as early as possible in the spring.

In November, 1911, Mr. Wildermuth wrote:

Mr. Packard and cotton growers throughout the valley report but little injury to cotton by this thrips this year. I found only two specimens of larvæ myself, and a few adults. It would seem as if the damage to cotton comes when cotton follows alfalfa. This year, there being but little alfalfa land put to cotton and more cotton following cotton, the damage was not so noticeable.

WILD PLANTS.

Of all food plants of this insect the wild spiny lettuce (*Lactuca scariola*) seems to be preferred, at least in the vicinity of Los Angeles. From early spring, when this plant comes up, until it dies down in the fall, it is usually badly infested by thrips. Many cases have been observed where other food plants, such as beans, etc., in the same field were only slightly infested, while the spiny lettuce near by was so badly attacked that many plants were dead. Furthermore, this weed is one of the commonest in the country, occurring abundantly in uncultivated or even in badly cultivated fields. In addition it grows up in dense clumps in all fence rows and roadsides, and the rights of way of the different railroads are densely packed by this plant.

When this weed first comes up in the early spring there is scarcely any vegetation, so that it offers an agreeable host to the bean thrips, especially as the foliage is very tender and juicy at that time. The thrips attack the first young leaves, and the larvæ, upon hatching from eggs deposited at that time, join the feeding adults. As soon as these become abundant, the leaves lose all or nearly all of the green leaf-content and turn white, after which they dry up and hang dead from the stalk. The infestation continues to spread to the younger leaves until the entire plant is killed.

The sow thistle (*Sonchus oleraceus*) has the same general distribution and is also a favorite food plant.

Wild heliotrope (*Heliotropium curassavicum*) is another favorite food plant late in the year. This plant does not start in the spring until quite late, and when it does appear above the ground generally escapes destruction by cultivation. Thus it occurs commonly in the beet and bean fields and in orchards, and in the fall is one of the chief food plants.

The bean thrips has also been found feeding and reproducing in numbers on *Euryptera lucida* and on one of the cucurbitaceæ, probably an *Echinocystis*, in a canyon north of Los Angeles. In the same locality it was later taken feeding and reproducing on *Gnaphalium californicum*, *Mirabilis californica*, *Eunanus brevipes*, *Chenopodium murale*, *Helianthus annuus*, *Atriplex* sp., wild turnip, *Erigeron canadensis*, and wild pea (*Lotus americanus*). It was also taken in the valleys feeding and reproducing on the Chinese cigarette flower (*Nicotiana glauca*), *Bidens pilosa*, *Verbascum virgatum*, *Polygonum aviculare*, and *Crepsis* (?) sp. The adults were also taken in the fall feeding on the foliage of a porch vine, *Tacsonia mellissimus*, and on the cultivated nasturtium (*Tropæolum majus*). Mr. A. C. Morgan found it on the underside of the leaves of the tulip poplar at Clarks-ville, Tenn.

This thrips has also been recorded as feeding on *Lotus glaber*, apple, peach, orange, wild vetch, burr clover, and radish.

After perusal of the above list of food plants it is easy to see how this insect can obtain a foothold in a cultivated crop in the late summer, especially as many of the wild plants die from maturity or lack of moisture, thus forcing the insect to migrate.

SEASONAL HISTORY AT COMPTON, CAL.

The life cycle of the bean thrips was observed at Compton for varying parts of the year, and because of the cooler and more even temperature prevailing there is quite extended and more nearly equal for the entire period of reproductive activity.

THE EGG.

The length of time required for the egg to hatch in the months of March, April, and May was not exactly determined. However, fresh

leaves of wild lettuce were collected on April 7 and they had a number of eggs in them very recently laid. The last of these hatched on April 24, making the length of incubation about 17 days, or possibly as many as 21 days. The average mean temperature for these 21 days was 59.1° F.

In July several adults of this thrips were confined over night on leaves of growing plants that were uninfested, and were removed on the following morning. In this way a number of eggs were obtained that hatched under absolutely normal conditions, as the plants were kept in an open-air insectary.

Table IV has been prepared to show the records of incubation for these eggs.

TABLE IV.—*Length of egg stage of the bean thrips in July at Compton, Cal., 1911.*

Date of oviposition.	Dates eggs hatched and number each day.								First egg hatched.	Last egg hatched.	Shortest incubation.	Longest incubation.	Total eggs hatched.
	July 23.	July 24.	July 25.	July 26.	July 27.	July 28.	July 29.	July 30.					
July 10	5	54	16	3	2	6	-----		July 23	July 28	<i>Days.</i> 13	<i>Days.</i> 18	86
July 11	-----	26	18	9	7	-----	-----		July 24	July 27	13	17	60
July 14	-----	-----	-----	-----	-----	8	15		July 28	July 29	13	14	23
													169

In this experiment 169 eggs hatched and the minimum length of incubation was 13 days and the maximum 18 days, but nearly 50 per cent hatched in just 14 days. During this total period the average mean temperature was 69.6° F.

Again, on August 20 adults were confined over night on a living plant of wild lettuce, and 4 larvæ hatched on September 4, and 7 on September 5, making the periods of incubation 15 and 16 days. During this time the average mean temperature was 66.3° F.

During the months of October and November the incubation is probably lengthened a few days and will take about 21 days, as the average mean temperature for these months was, respectively, 58.67° and 55.3° F.

THE LARVA.

The length of time occupied by this insect in the larval stage during the months of March, April, and May was observed during the year 1911 by confining larvæ that had just emerged in vials constantly supplied with fresh food. Table V gives the results of these observations. While in the first part of this period the length required was from 17 to 19 days, later it was shortened to 9 and 11 days. The average mean temperature for the first period, March 19 to April 7, was 61.5° F. and for May 14 to May 27 it was 61.1° F.

TABLE V.—*Length of larval stage of the bean thrips, Compton, Cal., March and May, 1911.*

Date larvæ hatched.	Number of larvæ hatched.	Larvæ pupating.		Length stage.		Average mean temperature.
		Date.	Number.	Minimum.	Maximum.	
				Days.	Days.	° F.
Mar. 19.....	8	{ Apr. 5 Apr. 6 Apr. 7	{ 1 2 1	17	19	61.5
May 14.....	7	May 24	1	10	11	62.1
May 16.....	15	May 26	4	10		
May 18.....	14	May 27	4	9	11	62.1

¹ Rest killed by heat.

During June and the first part of July this method of rearing larvæ to secure the length of instars was repeated, with the results shown in Table VI.

TABLE VI.—*Length of larval stage of the bean thrips in June and the first part of July, 1911, Compton, Cal.*

Exp. No.	Eggs hatched.		Larvæ pupated.		Total pupated.	Duration of stage.		Average mean temperature.
	Date.	Number.	Date.	Number.		Minimum.	Maximum.	
						Days.	Days.	° F.
1	June 15.....	5	{ June 28 July 1	{ 1 1	2	13	16	63.9
	June 29.....	50	{ July 10 July 11 July 12	{ 3 4 4	11	11	13	66.7
2	June 29.....	50	{ July 11 July 12	{ 7 4	11	11	12	
	July 1.....	50	July 13	3	3	12	.....	.....

Here the minimum for the larval stage was 11 days and the maximum 14 days.

In July larvæ were reared from eggs laid in normal growing plants, situated in an outdoor insectary under normal conditions. These experiments are all given in Table VII.

TABLE VII.—*Length of larval stage of the bean thrips in July, 1911, at Compton, Cal.*

Exp. No.	Eggs hatched.		Date and number of larvæ pupating.	Total larvæ pupating.	Length of larval stage.		Average mean temperature.
	Date.	Number.			Minimum.	Maximum.	
					Days.	Days.	° F.
1	{ July 23 July 24 July 25	{ 5 54 16	{ July 31, 85 larvæ feeding; Aug. 2, all but 10 left plant to pupate; Aug. 5, 10 prepupæ. Aug. 2, all larvæ left plant to pupate in cracks. These larvæ were feeding from 7 to 9 days and then left the plant.	85	10	12	68.8
2	{ July 24 July 25 July 26	{ 26 18 9					
3	{ July 28 July 29	{ 8 15					
			Aug. 9, number of larvæ pupated.		11		65.4

In these experiments the larvæ were observed to feed for a period of 9 to 10 days and then to leave the plant to pupate, and 10 to 12 days were required between hatching from the egg and changing to prepupæ.

During the year 1910 a number of larvæ that hatched on July 28 were observed to change to prepupæ on August 7, the total length of the larval stage being 10 days, with an average mean temperature of 72.1° F.

The length of this stage later in the summer and in early fall for this locality unfortunately was not observed, but was probably somewhat shorter for August and September and considerably longer in October and November.

THE PREPUPA AND PUPA.

As the prepupa and pupa are two distinct stages, although closely related, the length of each was separately determined. These two stages during the spring of 1911 required from 3 to 6 days for the prepupa and from 9 to 14 days for the pupa, or a total of from 14 to 19 days. The results are shown in Table VIII, with the average mean temperature for each experiment.

TABLE VIII.—*Length of prepupal and pupal stages of the bean thrips at Compton, Cal., during March to May, 1911.*

Exp No.	Larvæ changed to prepupæ.		Prepupæ changed to pupæ.		Adults emerged.		Length of stage.			Average mean temperature.
	Date.	Number.	Date.	Number.	Date.	Number.	Pre-pupal.	Pupal.	Total.	
1	Mar. 31.....	5	Apr. 3	5	Apr. 17	5	Days. 3	Days. 14	Days. 17	° F. 59.2
2	Apr. 10.....	1	Apr. 15	1	Apr. 24	1	5	9	14	59.5
3	Apr. 19.....	1	Apr. 25	1	May 4	1	6	9	15	57.9
4	Apr. 24.....	2	Apr. 29	1	May 10	1	5	11	16	56.9
	Total.....	9		8		8				

In the month of July these stages required from 1 to 4 days for the prepupa, and from 4 to 7 days for the pupa, or a total of from 5 to 11 days. The number that required less than 7 days, however, was very small. During this month the average mean temperature was 69° F.

Table IX shows the results of these experiments and the average temperature for each.

TABLE IX.—*Length of prepupal and pupal stages of the bean thrips at Compton, Cal., during July, 1911.*

Exp. No.	Changed to prepupa.		Changed to pupa.		Adults emerged.		Length of stage.			Average mean temperature.
	Date.	Number.	Date.	Number.	Date.	Number.	Pre-pupal.	Pupal.	Total.	
							Days.	Days.	Days.	° F.
1	July 1.....	7	July 5	7	July 11	2	4	6-7	10-11	71.7
	July 10.....	3	July 13	3	July 12	5				
			July 14	6	July 18	3	3	5	8	
2	July 11.....	7	July 15	1	July 13	7	3	4	7	70.1
			July 14	1						
	July 13.....	3	July 15	2	July 19	.....	1-2	4-5	5-7	
3	July 15.....	1	July 17	1	July 24	1	2	7	9	71.6
	July 16.....	1	July 18	1	July 24	1	2	6	8	
4	July 19.....	2	July 23	2	July 29	2	3	6	9	68.5
	July 20.....	2	July 24	2	July 29	2	3	5	8	

During the month of August, 1910, at Los Angeles, Cal., larvæ changed to prepupæ August 2 and the adults emerged on August 9, requiring 7 days for the prepupal and pupal stages. For this period the average mean temperature at Compton, 10 miles out, was 72.4° F. Another lot changed to prepupæ on August 7 and the adults emerged on August 15, giving a total of 8 days for the prepupal and pupal stages. The average mean temperature at Compton for the period was 71.4° F.

For the latter part of August and for September the length of these stages is nearly that required in July. However, in October this time is lengthened to some extent. Larvæ that changed to prepupæ on November 3, 1910, required until November 16 before the adults emerged, or a total of 13 days. The average mean temperature for the period was 59.9° F.

Records made of the length of the prepupal and pupal stages for November and December, 1910, as given in Table X, show that at that time of year the period required was greatly prolonged, the prepupal stage requiring from 7 to 9 days and the pupal stage from 20 to 24 days, making a total period of from 27 to 33 days. During this period the mean average temperature was 53.58° F.

TABLE X.—*Length of prepupal and pupal stages of the bean thrips for November, 1910, at Compton, Cal.*

Exp. No.	Changed to prepupa.		Changed to pupa.		Adults emerged.		Length of stage.		
	Date.	Number.	Date.	Number.	Date.	Number.	Pre-pupal.	Pupal.	Total.
							Days.	Days.	Days.
1	Nov. 14.....	1	Nov. 21	1	Dec. 12	1	7	21	28
2	Nov. 16.....	2	Nov. 23	2	Dec. 13	1	7	20-22	27-29
			Nov. 25		Dec. 15	1			
3	Nov. 17.....	7	Nov. 26	2	Dec. 15	1	8-9	22-24	30-33
			or 27.	4	Dec. 17	3			
	Total.....	10		9		7			

TOTAL LIFE CYCLE.

For localities with climatic conditions similar to those of Compton, the life cycle of this thrips will occupy during the early spring about 51 to 56 days, taking 20 days for the egg incubation, 17 to 19 days for the larval development, and 14 to 17 days for the prepupal and pupal stages.

During the months of June to October the life cycle of this thrips will occupy from 28 to 43 days, taking 13 to 18 days for the egg stage, 10 to 14 days for the larval stage, and 5 to 11 days for the prepupal and pupal stages.

During the rest of the breeding activity the life cycle must be even longer than in the spring, as in November, 1910, the prepupal and pupal stages alone occupied from 28 to 33 days, so that for the development of this insect during October, November, and the first of December at least 68 to 73 days must be required.

EMERGENCE FROM HIBERNATION.

In 1912 the adults began to emerge from hibernation at Hollywood, Cal., in January, and began oviposition at once. When this locality was visited on February 7, the adults were found to be feeding on the foliage of peas and beans in some numbers. They were also seen in copulation in many cases. A careful examination disclosed 4 young larvæ feeding on bean foliage, so that the adult must have laid the eggs at least by January 10. This field was situated on the foothills of what is termed a frostless belt, and it may be that this insect in mild winters might breed there during the entire period.

On February 17 adults were found feeding on pea foliage in Mission Valley, San Diego County, but no young were seen. February 23 the species was found as an adult feeding on pea vines in the truck farms around Los Angeles, and on March 13 adults were found feeding in small numbers at Compton, Cal. From then on the adults were common feeding on different plants, but not until April 17 were the larvæ found feeding in the open at Compton, although they were being reared in the open insectary at that place from material collected at Hollywood.

It would probably be better to say that this insect begins active reproduction at a varying time, those in the most protected places starting as early as January 10, and the others over the next 60 days. However, during the early spring the multiplication and spread seem to be very slow.

ENTRANCE INTO HIBERNATION.

As the month of October appears, the adults become sluggish, do less feeding and lay fewer eggs, and apparently many enter hiberna-

tion. The larvæ become much less numerous and require an extended period to complete their growth. In 1910 the last larvæ in numbers were observed in the field on November 20, while one was observed on December 1, and three on December 13, and during the first part of December these had all changed to pupæ or died. The last adult appeared on December 27. In 1911 the larvæ were not very abundant after the first week in October, and the last ones were observed in Los Angeles County on November 21.

NUMBER OF GENERATIONS.

In the section of the State in which this insect was under observation, the first spring generation may commence as early as January 10 and probably egg-laying by overwintering adults continues for a considerable time. As the period of oviposition is quite extended the different broods tend to overlap; still in midsummer there are certain periods when the majority of thrips present may be adults or larvæ. Up to April 1 there is probably one small full generation occupying about 56 days. During April and May a second generation will develop; then during the four months of June, July, August, and September there is one full generation for each month. For the rest of the period of the breeding activity we have probably a partial brood that extends over 68 to 73 days.

Thus during the year this insect has a small generation in both the early spring and late fall and five full generations during the rest of the time, or seven generations a year.

SEASONAL HISTORY IN THE IMPERIAL VALLEY.

The observations on the life cycle of this insect for Imperial Valley were conducted by Mr. V. L. Wildermuth at El Centro, Cal., in 1910.

EGG PERIOD.

Mr. Wildermuth confined adults in vials with fresh sprigs of alfalfa and kept the foliage fresh by wrapping the stems in moist cotton until the larvæ hatched from the eggs. While many eggs were secured by this method, large numbers died before hatching, as the foliage became too dry, but, as shown in Table XI, the egg stage varied from four days in a single case to five days in a lot of 20 eggs laid the last day of August. The length of the egg stage at that locality was only one-third as great as that observed by the writer in Los Angeles County, but this is due in a large measure to the high temperature of the Imperial Valley.

TABLE XI.—*Length of incubation of the eggs of the bean thrips, El Centro, Cal., 1910.*

Date of oviposition.	Number laid.	Eggs hatched.		Length of stage.	Average mean temperature.
		Date.	Number.		
July 27.....	2	Aug. 1	2	<i>Days.</i> 4½	° F. (1)
Aug. 11.....	(2)	Aug. 15	1	4	87.1
Aug. 31.....	(2)	Sept. 6	20	5	88.7

¹ Records missing.² Many.³ At Brawley.

LARVAL PERIOD.

The active feeding larva molts once before its final molt to the prepupal stage. This occurs in from one and one-half to two days after it hatches from the egg. The larva becomes full grown and changes to the prepupa in from four and one-half to five days. As might be expected from the great difference in the incubation period of the egg, the larval period in the Imperial Valley, as observed by Mr. Wildermuth, is much shorter than at Compton. These data are given in Table XII.

TABLE XII.—*Length of larval stage of the bean thrips at El Centro, Cal., during 1910.*

Exp. No.	Eggs hatched.		Molted.		Changed to prepupa.		Length.	Average mean temperature.
	Date.	Number.	Date.	Number.	Date.	Number.		
1	Aug. 15.....	1	Aug. 16	1	Aug. 19	1	<i>Days.</i> 4½	° F. 85.8
2	Aug. 18.....	3	Aug. 19	1	Aug. 22	1	4½	(1)
3	Aug. 26.....	1	Aug. 28	1	Aug. 31	1	5½	91.9
4	Sept. 1.....	1	Sept. 3	1	Sept. 5	1	4	89.7
5	Sept. 22.....	1	Sept. 24	1	Sept. 27	1	5	81.8
	Total.....	7	.....	5	.....	5	.....	.....

¹ Records missing.

PREPUPAL AND PUPAL PERIODS.

Unfortunately Mr. Wildermuth's records give a very small amount of data on the length of the prepupal and pupal periods, but in the six examples observed (see Table XIII) the stages varied from 2 to 3 days. While the writer was studying the greenhouse thrips the prepupal stage was often observed to last only a few hours, and this same condition probably occurs with the present species in the high temperature of the Imperial Valley.

TABLE XIII.—*Length of prepupal and pupal stages, El Centro, Cal., 1910.*

Exp. No.	Date changed to prepupa.	Date adult emerged.	Length of period.	Average mean temperature.
			<i>Days.</i>	<i>° F.</i>
1	Aug. 19.....	Aug. 21	2½-3	(1)
2	Aug. 22.....	Aug. 24	2	(1)
3	Sept. 6.....	Sept. 8	2-2½	2 84.9
4	Sept. 4.....	Sept. 8	3	2 85.1
5	Sept. 7.....	Sept. 9	2	2 87.0
6	Sept. 27.....	Sept. 29	2½	(1)

¹ Records missing.² Temperature at Brawley, U. S. Weather Bureau.

In the Imperial Valley the egg stage is from 4½ to 5 days, the larval stage from 4 to 5 days, and the prepupal and pupal stages from 2 to 3 days, making the total life cycle only 10 to 12½ days during the extreme summer temperature.

The eggs were deposited within 2 days from the time the adult females emerged, so that a new generation might occur every 14 days in midsummer. If the insect emerges from hibernation in the Imperial Valley at the same time as in Compton, there will undoubtedly be 1 generation in the early spring occupying 30 to 40 days, and then 2 generations a month for 5 or 6 months and 1 longer generation in the fall, or 12 to 14 generations a year. Indeed, with such rapid multiplication it is not strange that crops in the late fall become seriously infested.

SEASONAL HISTORY AT TEMPE, ARIZ.

Mr. Wildermuth during October and November, 1911, made some observations on the life cycle of this thrips at Tempe. These gave a life cycle of very nearly the same duration as in the Imperial Valley in the warm weather, but in November the cycle was lengthened considerably. He found that specimens collected as larvæ on October 30 did not emerge as adults until December 1. This shows the same effect of cooler weather on this insect that the writer observed at Compton, Cal.

Taking the results of Mr. Wildermuth's and the writer's observations on the bean thrips, there is a minimum life cycle of 10 days where the average mean temperature is about 88.75° F., and a maximum of about 73 days with an average mean temperature of about 53.58° F.

HIBERNATION.

This insect hibernates as an adult only, through most of its distribution at least. It may be that in the more southern portions of its range it breeds continuously throughout the year, but our observations in these localities mentioned have failed to show it.

In the section around Compton, Cal., the adults were found to hibernate in small numbers on the underside of leaves of nasturtium, sugar beets, wild heliotrope, and other plants. They were also found hibernating in some numbers in dead leaves and rubbish. When disturbed they were sluggish and made little effort to escape.

Mr. P. R. Jones (in litt.) says that around Lindsay, Cal., the adults hibernate in numbers in the navel end of the Washington navel orange. He also stated that in midwinter he had taken this thrips along creek beds hibernating on the underside of leaves of wild raspberry and blackberry which were still on the plants.

NOTES ON OCCURRENCE.

Apparently the different methods of cultivation bear strongly on the abundance of these insects and consequent injury they may cause to a crop. In Los Angeles County, where clean cultivation is not strictly followed out, it begins to breed in the spring on the wild food plants and increases more and more until in August it has reached enormous numbers. Before this the native plants are, many of them, either matured or destroyed by the thrips, and as a result it spreads more and more to the cultivated crops and trees that serve as hosts. During some years this occurs late in the season and very little real damage results, but if this insect should begin the year in fairly large numbers and under favorable conditions, great damage may result.

In Ventura County, in October, 1910, the author made a careful examination of the entire bean-growing section and found that the bean thrips occurred in extremely small numbers on the little vegetation remaining. At the same time it was extremely abundant around Compton. This condition seemed to be a direct result of the practice of the growers in Ventura of thoroughly plowing and cultivating the fields within a short time after the beans are harvested and keeping them in perfect condition until the next crop is planted. This advantage is increased because there is very little waste space where weeds can grow up. Our investigations during the past two years have shown that this insect is not abundant on cultivated crops in the spring or early summer, but that after this period it increases more and more, and in certain years injures them so severely as to cause much loss.

NATURAL CONTROL.

RAINS.

One of the largest factors in the destruction of thrips in some localities is the prevalence of hard, dashing rains. The author, while working in Florida with the greenhouse thrips, once observed

that crotons, which in the greenhouse were infested with thousands of thrips and which in June were placed outside and subjected to the Florida summer rains, when examined in September were so free from this insect that it was almost impossible to find specimens.

California, with its long dry season, does not obtain the same benefit, but even there the rains may reduce attacks of the bean thrips to some extent. On February 7, 1911, the writer observed a pea field that had from 5 to 8 adults on every plant. After this date there was a severe rain of several days' duration, and when the field was again examined, on April 1, it was almost impossible to find the thrips. Mr. Graf, writing from Puente, Cal., on October 6, 1911, noted that the larvæ were much scarcer than a week earlier, probably owing to a rainfall of one-half inch. Mr. Wildermuth, at Tempe, Ariz., wrote on October 5, 1911:

A search in the patch of alfalfa back of the office, where thrips had been very numerous for several weeks, failed to reveal very many thrips to-day. The heavy rain of yesterday and last night was probably responsible for washing them off.

In California, then, late rains in the spring may greatly diminish the numbers of this insect, or early rains in the fall destroy many that otherwise would enter hibernation.

NATURAL ENEMIES.

A great deal of attention has been given to the subject of natural enemies and some information obtained on this important feature of insect control.

In the fall of 1910 the larva of this thrips was discovered to be parasitized (see fig. 10) by a minute hymenopteron. This was described by Mr. J. C. Crawford as *Thripoctenus russelli* (see fig. 11). During 1911 this parasite was observed to work extensively in Los Angeles County on the bean thrips and seemed to destroy large numbers. Some collections of thrips larvæ gave as high as 70 per cent killed by the parasite. For a full account of this parasite the reader is referred to Technical Series 23, Part II, Bureau of Entomology, United States Department of Agriculture.

During 1911 the larva of a green lacewing fly (*Chrysopa californica* Coq.) was commonly observed feeding on the larva of this thrips. As this insect was observed so engaged in several localities in Los Angeles County, and in noticeable numbers, it probably kills a large number of thrips.

The larva of a syrphid fly (*Spharophoria sulphuripes* Thomson) was also observed on numerous occasions feeding on the larva of



FIG. 10.—The bean thrips: Prepupæ parasitized by *Thripoctenus russelli*. Much enlarged. (Author's illustration.)

the bean thrips, and in confinement larvæ were observed to kill and eat large numbers of the host.

The young of *Triphleps insidiosus* Say were noticed on many occasions feeding on the young of this thrips and undoubtedly aid in reducing its numbers.

The larvæ and adults of *Hippodamia convergens* Guér were frequently collected on plants infested with thrips, where they were busily engaged in feasting on the tender larvæ of the bean thrips.

On several occasions larvæ of a predaceous thrips, probably *Æolothrips fasciatus* L., when collected were feeding on the larvæ of the bean thrips.



FIG. 11.—A hymenopterous parasite, *Thripoctenus russelli*: Adult. Greatly enlarged. (Author's illustration.)

Mr. P. R. Jones informed the writer that at Lindsay, Cal., in 1910, he found a "nematode parasite working in the full-grown larvæ of the bean thrips."

A curious circumstance in connection with the observations made on the natural enemies of the bean thrips was the fact that in all of the predaceous forms noted the alimentary tract became bright red, undoubtedly due to the crimson or reddish pigmentation of the host.

ARTIFICIAL CONTROL.

CULTURAL METHODS.

In the case of crops planted over large areas and difficult or impossible to spray, such as beans, alfalfa, or cotton, cultural methods offer the most hope as a remedy for the bean thrips. Where this insect threatens injury it is recommended that these methods be used so far as possible. It is very important that the crops be given

careful, clean cultivation, so that all weeds may be kept down in the fields at all times, including the spring and fall. These same weeds, especially the different species of wild lettuce, should be carefully destroyed along the edges of all fields and fence corners and along the roads and railroad tracks. Cotton and beans should not follow in old alfalfa fields if the latter were badly infested with the bean thrips, and fields of these crops should be removed as far as possible from the alfalfa fields. They should also be planted as early as is consistent with good farming and encouraged by frequent cultivations and fertilizers where necessary to produce an early crop so as to escape the ravages of the bean thrips in the late summer.

As this insect feeds on such a variety of plants it is hardly possible that rotation of crops would aid materially in its control unless some crop could be found that is quite immune.

Where it is injuring alfalfa Mr. Wildermuth recommends disking and thorough renovation of the fields and good irrigation in order to give the plants as much chance as possible to make a quick growth.

SPRAYING.

The control of this thrips by spraying is impracticable for a crop such as alfalfa or cotton, and because of the low trailing vines of the bean will probably be successful with this plant only when the vines can be easily reached from the underside. In case injury to fruit trees is threatened it can be controlled by using the spray so successful against the pear thrips. This is a solution of $2\frac{3}{4}$ per cent nicotine, diluted at the rate of 1 part to 60 parts of water in a 6 per cent distillate-oil emulsion.¹

The distillate-oil stock emulsion, according to the formula of Foster and Jones, is made as follows:

Hot water	gallons..	12
Fish-oil or whale-oil soap	pounds..	30
Distillate-oil (raw) 30° to 34° Baumé	gallons..	20

Have the water boiling hot when put into the spray tank and add the soap immediately while the agitator is running at a good speed. When the soap is all thoroughly dissolved pour in the oil slowly, keeping the mixture well agitated while the oil is going into the tank. When all of the oil is in and well mixed, pump out through the nozzles at good pressure (not less than 175 pounds) into storage tanks.

No one should attempt to make this stock emulsion without a power spraying machine, as thorough agitation and high pressure are important requisites. Also, care should be used in having measurements reasonably exact, the water boiling hot, and the soap thoroughly dissolved before any oil is put in. This stock solution contains approximately 55 per cent oil, and to make a 3 per cent emulsion use $5\frac{1}{2}$ gallons of this stock in each 100-gallon tank.

¹ For a full account of this spray as used against the pear thrips, see Circular 131, Bureau of Entomology, U. S. Dept. of Agriculture, pp. 8-9.

A simpler formula and one that possibly will act quite as well on this insect, where it is exposed on the foliage, and one that will offer no chance for the burning of the foliage, has given good results in the destruction of *Heliothrips rubrocinctus* Giard in Florida. Mr. Edward Simmonds, of the Bureau of Plant Industry, advised the writer that a solution composed of 1 gallon of blackleaf tobacco extract, 1 pound of whale-oil soap, and 50 gallons of water gave excellent results in treating trees infested by this insect. This formula seems a little strong to the writer and he would recommend using the blackleaf at the rate of 1 part to 60 parts of water. In the place of this, a 40 per cent solution of nicotine can be substituted at the rate of 1 part to from 1,000 to 2,000 parts of water.

DISTRIBUTING THE PARASITE.

Possibly the parasite of this insect can be artificially distributed with good results to sections infested by this thrips where the parasite does not occur. For directions and methods of shipping this parasite, the reader is referred to Technical Series 23, Part II, Bureau of Entomology, U. S. Department of Agriculture, page 51.

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U. S. DEPARTMENT OF AGRICULTURE,
BUREAU OF ENTOMOLOGY—BULLETIN No. 119.

L. O. HOWARD, Entomologist and Chief of Bureau.

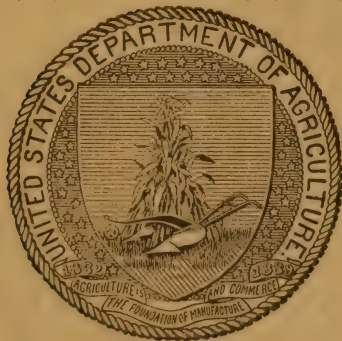
THE DISPERSION OF THE GIPSY MOTH.

BY

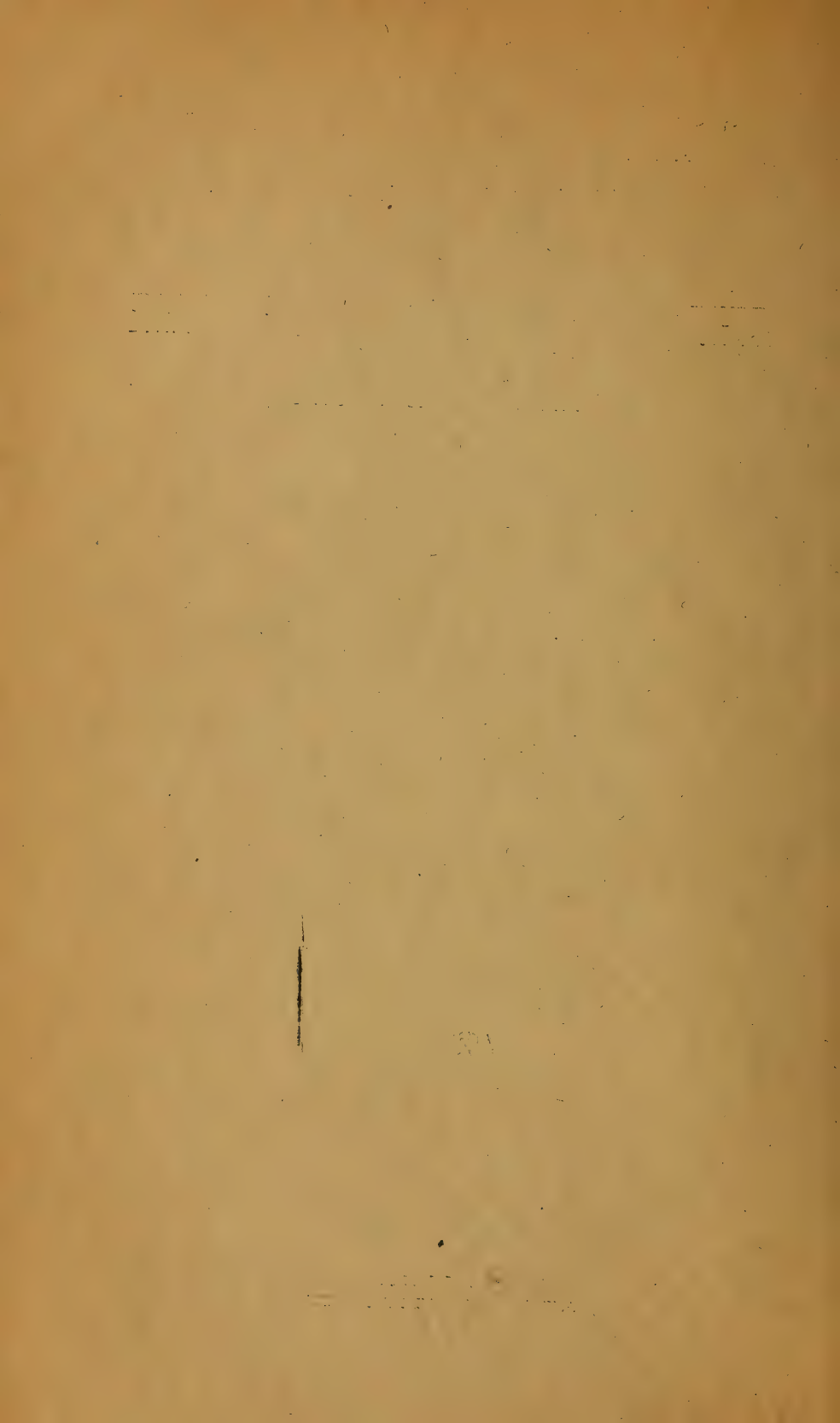
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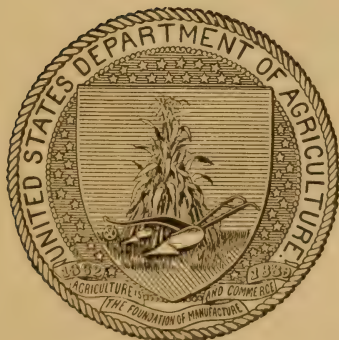
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BUREAU OF ENTOMOLOGY.

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PREVENTING SPREAD OF MOTHS.

LABORATORY.

(*At Melrose Highlands, Mass.*)

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LETTER OF TRANSMITTAL.

U. S. DEPARTMENT OF AGRICULTURE,
BUREAU OF ENTOMOLOGY,
Washington, D. C., July 24, 1912.

SIR: I have the honor to transmit the manuscript of a paper entitled "The Dispersion of the Gipsy Moth," which is a result of extensive studies made to determine the means by which this insect is spread. The gipsy moth has caused enormous injury to the horticultural, forestry, and shade-tree interests in the New England States, and the results of the investigations made have an important bearing on the proper methods of restricting the further spread of this serious pest.

I recommend the publication of this manuscript as Bulletin No. 119 of this bureau.

Respectfully,

L. O. HOWARD,
Entomologist and Chief of Bureau.

HON. JAMES WILSON,
Secretary of Agriculture.

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THE DISPERSION OF THE GIPSY MOTH.

INTRODUCTION.

The dispersion of any insect that has been introduced, accidentally or otherwise, into a new country offers an interesting opportunity to study the elements which aid in bringing about its transmission from point to point within that country, and this is particularly true concerning one of so great economic importance as is the gipsy moth. When the first work to suppress this insect was taken up in the early nineties an attempt was made to determine all the means by which the insect was spread, and since that time any data bearing on the spread of the pest have been eagerly sought and carefully studied in the hope that better methods could be found for its control. The region surrounding Medford, Mass., where the gipsy moth was introduced in 1869, is the center of one of the most thickly populated sections of the United States; hence there was an unusual opportunity for the spread of the insect by artificial means. In spite of the work that has been done and the observations that have been recorded it has remained until the last two years for a demonstration to be made of the manner by which this insect is spread, to the greatest extent, by natural means.

MEANS BY WHICH INSECTS ARE SPREAD.

One of the principal methods of insect locomotion and of spreading is by flying, and there is little chance of preventing the spread of a strong-flying introduced species which has become thoroughly established. The continued spread of the elm leaf-beetle and of the brown-tail moth illustrates how flying insects are dispersed.

There is, however, another class of insects which does not spread by flying. Several distinct types exist, and among them may be mentioned such insects as the San Jose scale and other closely related species. The structure of the females of this group is such that they remain fixed before becoming sexually mature; hence the distribution of the species is confined, so far as natural means is concerned, to the dissemination of the young, which have the ability to move about for a limited period. The adult insects are spread by artificial means on nursery stock and on living trees or shrubs that are shipped from one locality to another for planting or propagation. The brown-tail moth has also been distributed on nursery stock, but it is carried in this way while the small caterpillars are in the hibernating webs where they pass the winter.

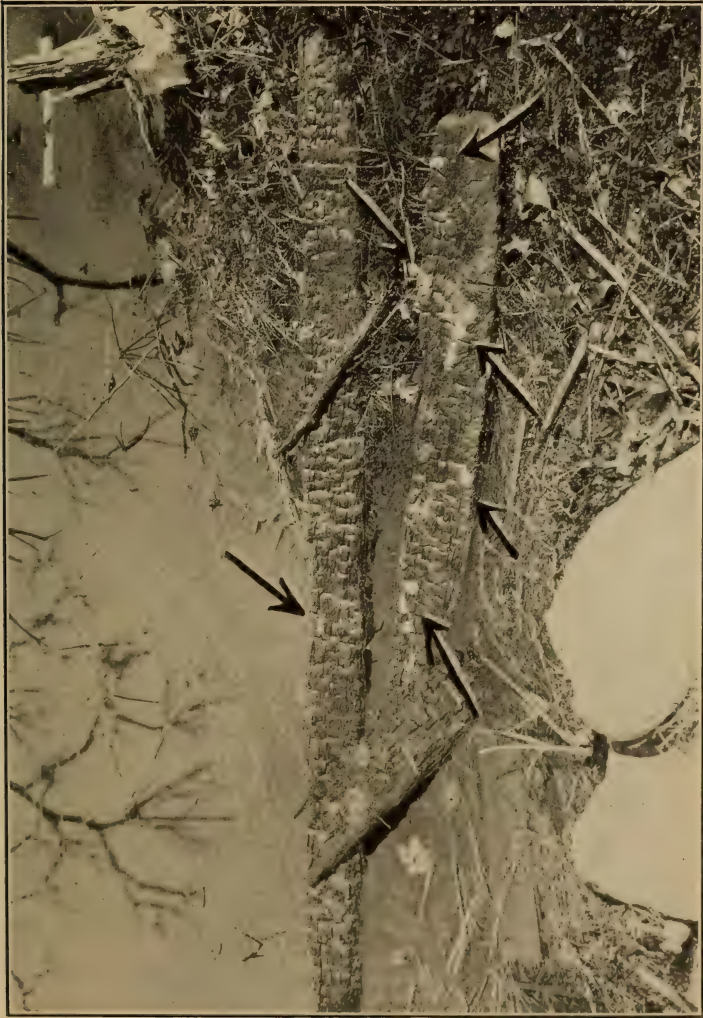
While the gipsy moth does not belong to the same class as the scale insects just mentioned, it resembles them inasmuch as it is not spread by the flying of the adult, for although the females are provided with wings, they are unable to fly, owing to the extreme weight of the body. Dispersion, therefore, is greatly restricted in this stage of the existence of the insect, and this is important, as it bears directly on the control of the species.

INVESTIGATIONS OF THE DISPERSION OF THE GIPSY MOTH.

Investigations which were carried on during the early nineties have been fully treated in the report on the gipsy moth by Forbush and Fernald, published by the Massachusetts State Board of Agriculture in 1896, natural and artificial dispersion being considered on pages 94-116. Although it appeared at that time that excellent opportunities were afforded for studying the dispersion of this insect, still it must be remembered that the pest was abundant in relatively few localities during the years covered by that report, especially when the conditions existing in later years are considered in comparison. It is evident that the extent of distribution of any insect depends largely upon the abundance of the species, and if large areas are badly infested migration is often necessary in order that many of the individuals may secure sufficient food.

The dispersion of the species, as treated in the above mentioned report, was considered as local and long distance. The former condition was brought about by egg clusters being broken and scattered by birds or other animals that frequent infested trees. Clusters were also carried on driftwood (see Pl. I), and those deposited on leaves (see Pl. II) were sometimes distributed by the wind. The caterpillars were occasionally found clinging to the bodies of animals or to the clothing of persons who had visited infested places and were carried short distances in this way.

Many colonies were established in remote districts by the carriage of the larvæ on vehicles, and egg clusters were sometimes transported on cordwood or lumber products shipped from infested forests. (See Pl. III.) The distribution of caterpillars upon vehicles was considered so important when the gipsy-moth work was begun in 1891 that inspectors were stationed along the main highways to stop and examine all vehicles and to destroy any caterpillars found before allowing them to pass out of the infested area. This precaution was entirely warranted in view of the discovery that many farms had become infested by the transportation of caterpillars on vehicles. Places infested in this manner, however, were usually occupied by milkmen, peddlers, swill gatherers, or persons whose business caused them to drive regularly to and from the city during the summer, or to neighborhoods that were badly infested with the gipsy moth.



GIPSY-MOTH EGG CLUSTERS ON CHARRED WOOD ON THE EDGE OF A STREAM, SAUGUS, MASS., MAY, 1912.
Showing how this species may be dispersed on driftwood. (Original.)



FEMALE GIPSY MOTHS DEPOSITING EGGS ON OAK FOLIAGE, MELROSE, MASS.

Arrows point to pupæ, moths, and egg clusters. (Original.)



LUMBER PILES AT YORK, ME.; GIPSY-MOTH EGG CLUSTERS ON UPTURNED BOARD AT RIGHT OF FOREGROUND.
(FROM HITCHINGS)

The efficient work which was carried on by the Massachusetts State Board of Agriculture during the early nineties rendered the continuance of vehicle inspection unnecessary, as the moth had been greatly reduced in numbers and very few badly infested localities could be found. At the time the work was abandoned in 1900, 34 towns and cities surrounding Boston were slightly infested. A few isolated colonies were present outside of the limits of this area, but in most cases these had been reduced almost to the point of extermination, and in several colonies none of the insects had been found for two or more years, in spite of the fact that careful examinations were made annually. It should be said that very little if any of the territory in the infested area was what would be considered now as badly infested, and owing to the thorough manner in which the work was prosecuted the danger of spread was reduced to a minimum.

CONTROL WORK ABANDONED.

In the winter of 1900 suppression measures were abandoned by the State of Massachusetts, but during the next five years considerable individual effort was expended to protect the trees in the residential sections, particularly by owners. The infestation became so serious, however, in the summer of 1904, and the depredations of this insect were so severe, owing to its remarkable increase in numbers, that action was taken by the State in the spring of 1905, and money provided for the purpose of affording relief and preventing the destruction of trees in towns and cities as well as of attempting to control the moth throughout the infested area.

The State force was organized by Supt. A. H. Kirkland, and conditions in the territory, which was the central part of that which was infested when the work was stopped, are well described by the following extract from his first annual report.¹

As would have been expected, during the year 1900 and 1901 but little notable damage was caused by the gipsy moth, although evidence was not wanting to the trained observer that it was rapidly multiplying in woodlands and on neglected private estates. It was apparent that nonresident property owners particularly paid practically no attention to the increase of the insect and that farmers and others owning infested woodland areas were unwilling, because of the expense, to fight the insect. In 1902 numerous estates were severely injured throughout the central district, while woodland colonies of some magnitude had developed from which the insects were swarming in all directions. The summer of 1903 showed that the moth had established itself again in alarming numbers in various parts of the infested district. Serious colonies had developed in the woods of Arlington, Medford, Saugus, and Malden, and the Lynn Woods colonies had assumed notable proportions. In 1904 it was apparent to all that the gipsy moth had developed to a remarkable extent, reinfested the areas from which it had been cleared, and even extended its bounds into previously noninfested

¹ First Annual Report of the Superintendent for Suppressing the Gipsy and Brown-Tail Moths, 1906, p. 12.

territory. The caterpillar outbreak was sufficient to convince every tree lover of the necessity of concerted action against the moths. While in many places in the afflicted district the trees under the charge of municipal authorities were cared for with considerable success, private estates and woodlands in June and July presented shocking scenes of devastation. In many places the work of fire could not have been more thorough or alarming. From Belmont to Saugus and Lynn a continuous chain of woodland colonies presented a sight at once disgusting and pitiful. The hungry caterpillars of both species of moths swarmed everywhere; they dropped on persons, carriages, cars, and automobiles, and were thus widely scattered. They invaded houses, swarmed into living and sleeping rooms, and even made homes uninhabitable.

GIPSY-MOTH WORK RESUMED.

It must be noted that the conditions above described were most favorable for the dispersion of this insect, and in order to determine so far as possible the territory which had become infested, inspectors from the office of the superintendent made an examination of a large area outside of that known to be infested when the work was stopped. Of necessity this examination was hurriedly done, owing to the fact that a sufficient number of trained men could not be secured in the limited time available, and also because a large number of the more experienced workers had to be employed in fighting the intolerable conditions in the central towns. The results of the scouting work, however, showed that the gipsy moth was present in 124 towns and cities in Massachusetts. Seven infested towns were also found in New Hampshire, extending from the Massachusetts line along the sea-coast to and including Portsmouth, so that the entire infested area proved to be six times greater than when the work was abandoned. Each year since 1905 more or less scouting work has been done by the State of Massachusetts in the towns outside of the known infested area, and in Maine, New Hampshire, Rhode Island, and Connecticut large sections have been examined by scouts working under the direction of Mr. D. M. Rogers, superintendent of moth work for the Bureau of Entomology, United States Department of Agriculture, and every year additional infested territory has been found. As a rule very few egg clusters are found in the outside towns, but it should be stated that the examination is confined to the roadsides, residential sections, and orchards, it being impossible to examine all the large forest areas involved.

The same factors which previously resulted in the dispersion of the insect were found to be operating, but the danger had been greatly increased owing to the development of many high-speed and long-distance trolley lines which conveyed people from the centers of population to the rural districts rapidly and in many cases without changing cars. These increased transportation facilities afforded an excellent opportunity for the distribution of gipsy-moth

caterpillars, and the presence of the insect in woodland surrounding lakes and ponds which were frequented by camping parties was the natural result. During midsummer, when caterpillars were abundant, they could frequently be seen crawling on the clothing of people on electric cars and sometimes have been observed on the seats and running boards. In this way they are often carried considerable distances.

THE AUTOMOBILE AS A MEANS OF DISPERSING THE GIPSY MOTH.

Perhaps no single form of transportation has caused so wide a dispersion of this insect as the automobile. When the gipsy moth was most abundant during the nineties it was seldom possible for caterpillars to be conveyed on teams or wagons more than 20 miles in a single day, but with the advent of the automobile this danger was greatly increased. In fact, since this mode of travel has become popular the traffic between the cities in eastern Massachusetts and the seashore and mountain regions in Maine, New Hampshire, and Vermont has increased remarkably, and the spread of the insect has been proportionately greater.

The lines of automobile travel are usually along trunk roads, many of which are bordered by badly infested woodland. These conditions afford an excellent opportunity for the young caterpillars to spin down from the trees and to be carried away by any moving object with which they come in contact. Cases are on record where city residents who own country or seashore places have caused them to become infested by journeying back and forth by automobile. So many cases of this kind have been found that it is now considered one of the easiest means by which the insect is spread. Automobile traffic is very heavy in June, when the gipsy moth is most likely to be carried in the caterpillar stage.

OTHER MEANS OF DISPERSING THE GIPSY MOTH.

Another means by which the gipsy moth is dispersed to outlying regions is through the unintentional carriage of caterpillars or egg clusters by visitors or travelers. In 1906 this insect was found in small numbers on the grounds of the National Soldiers' Home at Togus, Me. The nearest known infestation at that time was 81 miles away, and, from the condition of the infestation and the circumstances connected with it, it seemed probable that the insect had been brought there either in the egg or caterpillar stage on the clothing or among the effects of some of the inmates or visitors who came from the infested area in Massachusetts. Isolated infestations are continually being found in towns some distance from the infested area, especially on farms or in camps where parties from Boston and vicinity spend their summer vacations.

In the fall of 1910 a flourishing gipsy-moth colony was found on a farm at Charlton, Mass. The worst part of the infestation was in a small orchard near the farmhouse and in a row of trees some distance away which bordered on cultivated land. Inquiry showed that for a number of years it had been the custom for the owners of this farm to take children from Boston and vicinity for summer boarders. The vacation of each boarder usually lasted about two weeks, so that they were continually changing, and there is no doubt that gipsy-moth caterpillars or egg masses were brought from the infested regions in the baggage of the visitors.

Many similar cases might be cited, but this will suffice to illustrate the ease with which this insect may be carried long distances.

In December, 1909, a flourishing colony of the gipsy moth was found in the residential section of Wallingford, Conn. This is more than 100 miles from the nearest badly infested area. Examination showed that the worst infested trees were in the business section, and many of them were in the rear of a grocery and provision store. Supplies of vegetables, such as early lettuce, cucumbers, and tomatoes, had been received in season by this store from market gardens located near Boston, and there seems to be little doubt that egg clusters of the gipsy moth had been transported inadvertently on the boxes or in the packing material.

RELATION OF BIRDS TO THE DISPERSION OF THE GIPSY MOTH.

During the past few years the scouting operations in Massachusetts and New Hampshire have resulted in the discovery of gipsy-moth colonies in regions inaccessible to travel, and often in places which would seldom, if ever, be frequented by man. This condition of affairs has occurred so often, and an explanation for the presence of these colonies became so difficult, that it seemed desirable to take up the subject in a more thorough-going manner for the purpose of determining whether the insect might be distributed by some other means. In some of these cases it is possible that the colonies might have started from caterpillars that had been dropped by birds, but the distances between many of them and known infested regions were so great as to render this theory in most cases highly improbable. Furthermore, when caterpillars are picked up by birds they are usually injured to a greater or less extent, and the chances of their developing so that vigorous colonies would result in a few years are very remote. Another factor in relation to the influence of birds on the spread of the gipsy moth, and one which has received much serious consideration, is the possibility of their feeding upon the eggs of the species and distributing them in the excrement. If fertile eggs of the gipsy moth should be eaten and pass through the alimentary canal of some of our insectivorous birds without sustain-

ing injury, it would undoubtedly offer a valid explanation of the cause for some of the outlying colonies which have been found. In the report of Forbush and Fernald, already cited, detailed accounts are given of the part played by practically all the insectivorous birds which are at all common in eastern Massachusetts. At the time the observations were made a large number of trained field observers were constantly employed, and few, if any, of these reported that birds were found feeding upon eggs of the gipsy moth. In fact, the report states that the only bird that has been found feeding upon these eggs in the field is the English sparrow, and, as it is normally a grain-feeding species and one that frequents cities or centers of population, it is doubtful whether the moth would be dispersed to any great extent if it were possible for the eggs to pass through the bird without injury.

Fortunately, during the winter of 1909-10 two sets of experiments were conducted for the purpose of determining whether gipsy-moth eggs would pass through the alimentary canal of birds without injury. These tests were made independently, and in both cases it was necessary to disguise the eggs in other food or force the birds to feed upon them. One set of experiments was begun in February, 1910, by Mr. C. W. Collins,¹ of the parasite laboratory of the Bureau of Entomology. He used a number of English sparrows and a single pigeon.

The sparrows were fed by placing gipsy-moth eggs in their mouths and requiring them to take a swallow of water to wash them down. Of 356 eggs fed in this way 142 were found intact in the excrement and the balance were broken during the process of digestion or remained in the gizzard. Only seven eggs hatched, which shows that under this artificial treatment the chances for survival of the eggs are very small. None of the eggs fed to the pigeon hatched after being voided.

These experiments indicate the extreme improbability of either of these birds selecting gipsy-moth eggs for food, and the chances of the insect being disseminated in this way appear very slight, both on account of the injury to the eggs in passing through the bird and because the distances of migration of the species are relatively small.

The other set of experiments was conducted by Mr. Wm. Rieff,² of the Bussey Institution, Harvard University, during March of the same year. As no native birds were available for the tests the following species were used: German canary bird, English yellow-hammer, English chaffinch, Japanese robin, screech owl, and carrier pigeon. The eggs were disguised in food, such as bread crumbs. In the case

¹ Some Results from Feeding Eggs of *Porthetria dispar* to Birds. Journal of Economic Entomology, vol. 3, no. 4, Aug., 1910, p. 343.

² Some Experiments on the Resistance of Gypsy Moth Eggs to the Digestive Fluids of Birds. Psyche, vol. 17, No. 4, Aug. 1910, p. 161.

of the Japanese robin they were placed inside the larvæ of the meal beetle (*Tenebrio molitor*), while those fed to the screech owl were inserted in a freshly killed mouse.

Of 52 eggs that passed through the Japanese robin three hatched, while of 112 eggs vomited by the screech owl with the remains of the mouse seven hatched. No hatching resulted in the experiments with the other birds.

The writer says:

To sum up the details of these various experiments it is seen that gipsy-moth eggs can withstand the action of the digestive fluids of birds belonging to at least two families, Turdidæ and Bubonidæ, without suffering any, or only slight injury. In regard to the large family, Fringillidæ, also an insectivorous group, I am inclined to believe that these birds might also occasionally distribute gipsy-moth eggs in spite of the negative results obtained in my experiments.

These conclusions seem too sweeping because of the large percentage of the eggs that failed to hatch, and when the conditions under which the birds were fed is considered it is doubtful whether comparable results would be secured under natural conditions.

The Bubonidæ and Fringillidæ are not, for the most part, insectivorous birds, and it is doubtful if the latter would, except in rare instances, eat eggs without crushing them or at least attempting to break away their outer covering, as this is their usual habit when feeding on seeds, which are their natural food.

Whether eggs would pass through the alimentary canal of some of our less domesticated insectivorous birds unharmed is an open question, and one very difficult to settle, owing to the fact that these wild species can not be experimented with in confinement in any satisfactory way. It should also be noted that the digestive process in birds is more rapid under natural conditions than when they are confined for experimental purposes; hence it may be that in nature a larger percentage of eggs would withstand the digestive action, but the distance that they could be carried would be correspondingly reduced. The main question, however, appears to be whether birds actually eat eggs of the gipsy moth in the field.

Men engaged in the moth work frequently find egg clusters which have been broken, and sometimes in such a condition that one might conclude that they had been pecked at by birds. Clusters are sometimes broken by squirrels or other animals, and not infrequently this is charged up to birds. Mr. John A. Farley, one of the agents of the Massachusetts State forester's office, reports the following observation, which shows how carefully matters of this nature must be investigated in order to prevent error. On visiting a wooded area where it had been reported that birds were feeding on gipsy-moth eggs and where the clusters showed every indication that this

conclusion was correct, he found that the chickadees (*Penthestes atricapillus*) were working among the clusters and were apparently feeding. On making a more thorough examination he found that a few small white-pine seeds had been stored away in the cavities that were made by the birds in the gipsy-moth egg clusters. No eggshells or other evidences of feeding were found, and later Mr. Farley saw the birds depositing the seeds. Later in the season an examination was made and the seeds previously secreted were missing. Dissections have shown that pine seeds are a favorite food of this species and that they are often collected and stored for a winter food supply. The reliability of these data is unquestioned and throws an interesting light on the subject.

It has been suggested by Mr. William Brewster, the well-known ornithologist of Concord, Mass., that the gipsy moth may be spread in the egg stage by crows, hawks, and other large birds that make nests (Pl. IV) of large twigs, as it would be possible for them to carry material which was infested with egg clusters. This may happen in some cases, but it seems probable that it would result in local rather than long-distance dispersion.

In view of the results secured by the experiments above mentioned and of the observations cited it seems that the evidence is wholly inadequate to prove that birds were responsible for distributing the gipsy moth to the large area which was annually becoming infested. Furthermore, towns where only one small infestation was found might, the following year, be infested in 20 or 30 different localities, all of which were remote from influences which would favor artificial means of spread. As the first infestation found in a town is usually small and is thoroughly treated, no reasonable explanation could be given for the presence of so many colonies the following year. The fact, also, that many of these outbreaks were located in places that were seldom frequented by men or animals indicated strongly that some other natural means must assist the insect in becoming generally dispersed.

CONTINUED DISPERSION OF THE SPECIES UNEXPLAINED.

For several years this matter was thoroughly considered by the officials connected with the gipsy-moth work, but it seemed impossible to come to any conclusion as to the means whereby so many small isolated colonies had become established. The theory was advanced that occasionally one of the female moths, developed in a badly infested colony where the adults were abnormally small on account of an insufficient food supply for the larvæ, might be able to fly, and in this way cause the dissemination of the pest. No facts to prove this theory have ever been secured, and although this might happen occasionally it wholly fails to explain the reason for numerous small

colonies which are found long distances from any badly infested area. Isolated colonies have been usually so far away from infestations that it would have been practically impossible for small females to have covered the distance by flying.

SUGGESTIONS CONCERNING THE SPREAD OF LARVÆ BY THE WIND.

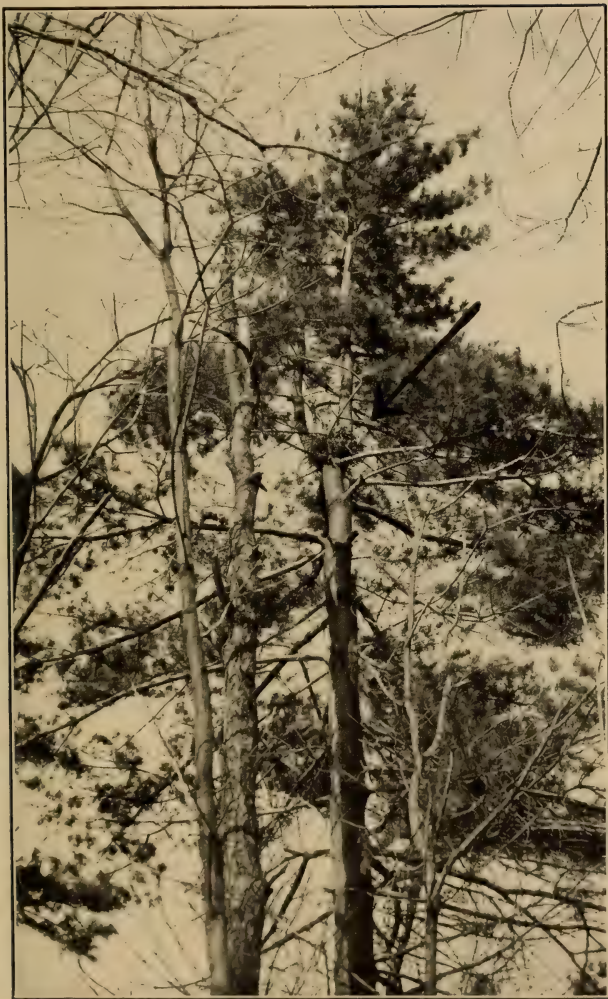
In the fall of 1909 Prof. E. D. Sanderson, who was then entomologist to the New Hampshire Agricultural Experiment Station, and who was deeply interested in the work of suppressing the gipsy moth, suggested that the caterpillars of this insect might be carried by natural means, and later he wrote to Dr. L. O. Howard, Chief of the Bureau of Entomology, calling attention to an article in the Standard Natural History relative to the peculiar hairs on the young caterpillars and suggesting that they might assist the larvæ in being carried by the wind. An examination of the literature showed that the matter had been mentioned by Forbush and Fernald in 1896 and that the hairs had been described by Wachtl and Kornauth in a publication relating to experiments in the forests of Austria in 1893. This paper deals principally with hairs of peculiar structure which are found in the first-stage larvæ of the nun moth (*Psilura monacha* L.) and states that similar hairs are found on the first-stage larvæ of *Porthetria dispar*.

These hairs are not present on the caterpillars in the later stages, and as they are provided near the base with a globular enlargement, which the authors believed to be filled with air or gas, they were called aerostatic hairs and the globes aerophores. They state that the first-stage nun larvæ are carried long distances by the wind, and one might assume that the same is true of the gipsy-moth larvæ, as they are provided with similar hairs.

A microscopic examination of one of these first-stage caterpillars shows that two kinds of hairs arise from the tubercles which are arranged in rows on the body. Only a few slender acuminate hairs, some of which are nearly half as long as the caterpillar, arise from each tubercle (Pl. V), but many short hairs are present which have a small globular swelling near the base. Whether these aerophores actually aid in making the caterpillars more buoyant, as is suggested by the authors above mentioned, is not positively known, but it was of great importance to know whether dispersion is actually brought about by means of the small larvæ drifting in the wind.

EXPERIMENTAL WORK.

In the spring of 1910 a preliminary experiment was tried in the laboratory by releasing caterpillars, which had been encouraged to spin as much silk as possible, in front of an electric fan. Although



CROW'S NEST IN TOP OF PINE TREE, POSITION INDICATED BY
ARROW.

Gipsy-moth egg clusters are frequently found in or around such
nests. (Original.)



FIG. 1.—FIRST-STAGE LARVA, SHOWING THE TWO KINDS OF HAIRS. ENLARGED.
(ORIGINAL.)

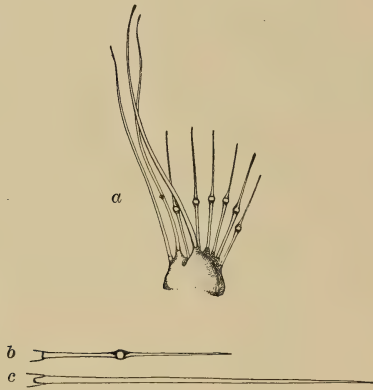
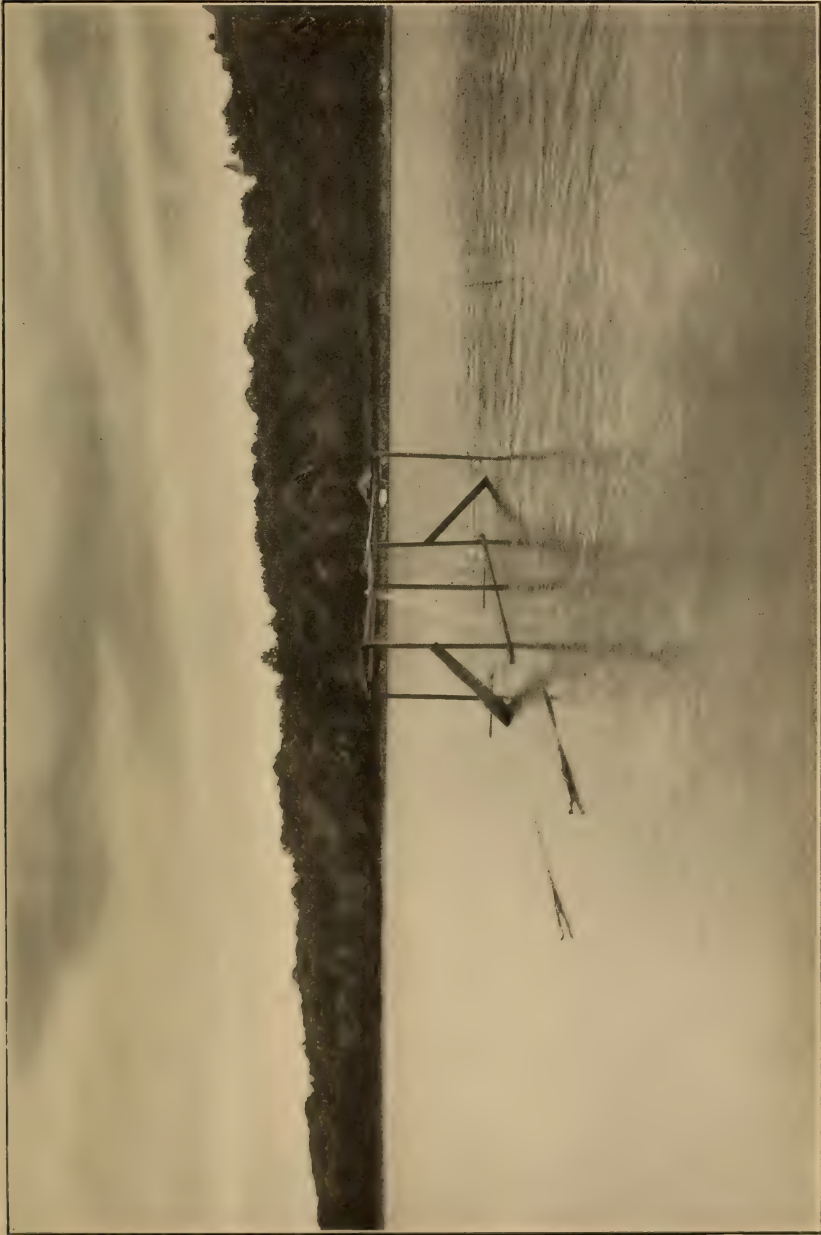


FIG. 2.—*a*, TUBERCLE FROM FIRST-STAGE LARVA, SHOWING HAIRS; *b*, AEROSTATIC
HAIR; *c*, ACUMINATE HAIR.

a, Much enlarged; *b*, *c*, more enlarged. (Original.)

GIPSY-MOTH CATERPILLAR SHOWING AEROSTATIC HAIRS.



TRAP MOORED IN POND TO TEST AVIATION OF GIPSY-MOTH LARVÆ. (ORIGINAL.)

it was very difficult to determine how far they might be carried under such conditions, owing to the small size of the rooms where the experiment was tried, it was possible in a few cases to secure specimens which had drifted from 20 to 30 feet from the fan. This led to an attempt to test the matter under outdoor conditions.

Arrangements were made with Mr. L. H. Worthley, then assistant forester of Massachusetts, whereby the tests would be made cooperatively with the department which he represented. Supplies and assistance were furnished by the State, and several men employed by the Bureau of Entomology attended to certain parts of the work. Many valuable suggestions were secured from Mr. Worthley, and from Messrs. D. M. Rogers and W. F. Fiske of this bureau. In carrying on the tests especial credit is due to Mr. C. W. Collins, who assisted in many of the experiments; to Messrs E. A. Proctor, J. V. Schaffner, and K. W. Brown for assistance and suggestions; to Mr. H. R. Gooch, who constructed the screens and apparatus used; to Messrs. C. W. Stockwell, F. H. Mosher, and John E. Dudley, jr., for helpful suggestions and for recording data on several phases of the work; and to Messrs. H. S. Barber, Melvin Guptill, H. A. Preston, and W. N. Dovenor, who prepared the photographs and accompanying illustrations. Suggestions which had a practical bearing upon the tests were made by those mentioned and by many others connected with the work at the parasite laboratory, so that all have contributed to the results which will be given.

For the weather conditions in Massachusetts we are indebted to Mr. J. W. Smith, district forecaster of the Weather Bureau, United States Department of Agriculture, at the Boston office. Data have also been secured from local forecaster Edward P. Jones, at Portland, Me., and from local forecaster E. C. Vose, at Concord, N. H., who have very courteously allowed the records of their offices to be freely used.

Plans were made to carry on several experiments out of doors as soon as the caterpillars began to hatch, and for this purpose a number of favorably situated localities were selected. In each case a screen of galvanized-iron wire was attached to a wooden frame, and after the netting had been treated with a thin application of tree tanglefoot it was set up so that caterpillars were likely to drift upon it if carried by the prevailing wind.

EXPERIMENTS AT LINCOLN, MASS.

The first trap was placed on a raft (Pl. VI) which was moored near the center of Sandy Pond, Lincoln, Mass. Two screens, each 12 feet long and 6 feet high, were placed at right angles so as to form a cross. The screen used was ordinary poultry wire having a mesh about 1 inch in diameter. The woodland surrounding this pond was

moderately to badly infested with the gipsy moth, and it was expected that if the young caterpillars were carried by air currents it would be possible to secure some of them in the tanglefoot which was applied to the wire netting. The pond is about a mile and a half long and three-fourths of a mile wide. As there are two small islands on which brush and sprouts were growing near the west side, an attempt was made to anchor the raft as nearly as possible at a point midway between the islands and the opposite shore. The raft was constructed April 25, 1910, and an attempt was then made to anchor it in the center of the pond. Owing to the high wind it was found impossible to do so, therefore it was anchored near one of the small islands, where it remained until May 2, when the anchorage was changed to the center of the pond. On this date the screens were examined, but no larvæ were found in the tanglefoot.

On May 9 the pond was visited, and it was found that the raft had drifted from its anchorage to the shore at the northeastern end of the pond. Infested woodland was present within 200 yards of where the raft lodged. The tanglefoot was examined, but no caterpillars were found. Owing to the strong wind it was impossible to tow the raft to the center of the pond, so it was allowed to remain where it was found.

On June 9 a visit was made to this trap for the purpose of making the final examination and dismantling it. A single caterpillar was found in the tanglefoot, which proved upon a careful examination to be a first-stage gipsy-moth larva. Owing to the difficulty of thoroughly examining the wire screen, because some of the tanglefoot had become rather hard and also because of the presence of an innumerable number of Micro-Diptera and other small insects, the screen was taken from the wooden form and brought to the laboratory, where later in the season it was cut up into small strips and thoroughly examined. This work was done by Mr. J. V. Schaffner and Mr. Emery Proctor, but no other gipsy-moth caterpillars were found upon it. During the first part of the experiment the weather was cool, which probably resulted in the young larvæ moving about but little, and this may explain why more caterpillars were not caught in the trap. Attention should be called to the small area of screen which was exposed, and in the light of future experiments it does not appear strange that no more caterpillars were secured.

EXPERIMENTS IN LYNN WOODS, MASS.

It did not seem practical, however, when the experiment was planned, to attempt to settle the question by making one test. Several other screens were constructed, and one made in a similar manner to the one used on the raft at Lincoln was placed on top of an obser-

vation tower at Mount Gilead in the Lynn Woods. (Pl. VII.) The arms on these screens were 10 feet long and 4 feet high. The trap was placed at the top of a tower 50 feet from the ground and fully 25 feet above the tops of the tallest trees. A few caterpillars were feeding on April 29, the date when the trap was installed.

The object of this experiment was to determine, if possible, whether caterpillars could be caught high in the air. The woodland surrounding this tower was badly infested, and later in the season a considerable area was completely stripped of foliage. On May 4 the trap was examined, but no caterpillars could be found. A large percentage of the gipsy-moth caterpillars had hatched, but most of the larvæ were still on the egg clusters, although some were feeding. The weather was cool, and only a slight wind was blowing.

The trap was examined on May 7, 11, 16, and 17, but no caterpillars could be found. On May 28 another examination was made with the same result. In woodland the caterpillars were now in the second, third, and a few in the fourth stage. The weather was cool, and very few were spinning down from the trees. On June 7 another examination was made, and on the 13th the screen was moved and brought to the laboratory, where it was examined later in the season by Messrs. Proctor and Schaffner, but no gipsy-moth caterpillars were found.

EXPERIMENTS AT CLIFTONDALE, MASS.

Another experiment was conducted near Cliftondale, Mass. Permission was secured to drop wire screens, which had been tanglefooted, from the sides of a high water tower (Pl. VIII) at the old Saugus race track, which borders a large area of salt marshes. These screens were manipulated with ropes and pulleys in such a way that they could be raised and lowered in order to make examinations. On one side of the tower, to the eastward, no trees were growing for a distance of about 2 miles, and the nearest trees in any direction, except for a few willow sprouts growing along the edge of the race track which will be mentioned later, were a quarter of a mile distant.

Two screens, 34 feet long and 6 feet wide, were dropped from the east side of the tower, while another screen of the same dimensions was suspended on the west side. They were placed in position April 30, 1910, and were examined at intervals until the middle of June. On May 11, a single gipsy-moth caterpillar was found on one of the screens on the east side of the tower, 25 feet from the ground. On May 18 a stock of newly hatched gipsy-moth caterpillars was liberated in the marsh 1,500 feet south of the tower at several stations, the idea being to give an opportunity for the larvæ to be carried by the wind to the tanglefoot screens. No caterpillars were found

on the screens as a result of this liberation. When the experiments were started it was planned to examine thoroughly a few willow sprouts, which were growing along the race track not far from the water tower, but on account of the pressure of other work this was neglected. In making an examination of the screens May 28 it was found that several old egg clusters and a considerable number of caterpillars were present on a clump of willow sprouts about 25 feet from the screen on the west side of the tower. In spite of this, however, no caterpillars were found on this screen during the season. There is a bare possibility that the caterpillar found on the screen on the opposite side of the tower may have come from some of these willow sprouts, but it is doubtful whether this is the case. The screens were removed June 13 and examined at the laboratory in the same manner as those already mentioned, but no other caterpillars were found.

The foregoing experiments were carried on under natural conditions and on a large scale, and in addition two other tests were made by Mr. Mosher. One large screen was built in the form of a cross, the same as the one placed on the tower at Mount Gilead. It was set up on land at Manchester, Mass., where the forest had recently been cut. Large trees surrounding this area were badly infested with the gipsy moth, and some additional data would probably have been secured from this experiment if a forest fire had not run through the area where it was conducted.

Another raft was constructed at Chebacco Lake in Essex, Mass., similar to the one used at Sandy Pond, but owing to bad weather and high winds it was impossible to anchor it securely in the center of the lake until it was too late to secure the data desired in the experiment. Before these tests had been carried very far it appeared desirable to check up the results in a more definite way, and in order to do this a series of experiments were planned, which were carried on by Mr. C. W. Collins and the writer on the salt marshes (Pl. IX) between Lynn and Revere, Mass.

EXPERIMENTS ON LYNN MARSHES, MASS.

A box of egg clusters containing many newly hatched larvæ was attached to the top of a pole about 6 feet from the ground. This point was used as a central station and was half a mile or more from any tree or tree growth. One end of the box (Pl. IX, fig. 1), containing the egg clusters and caterpillars, was partly cut away with a knife, while in the other a small hole was made to allow the wind to blow through the box. Small screens, 2 feet wide and 6 to 8 feet long (Pl. X), were attached to stakes which were sharpened so that they could be pressed into the ground; so that when these screens were set up they were about 5 feet above the ground. They were

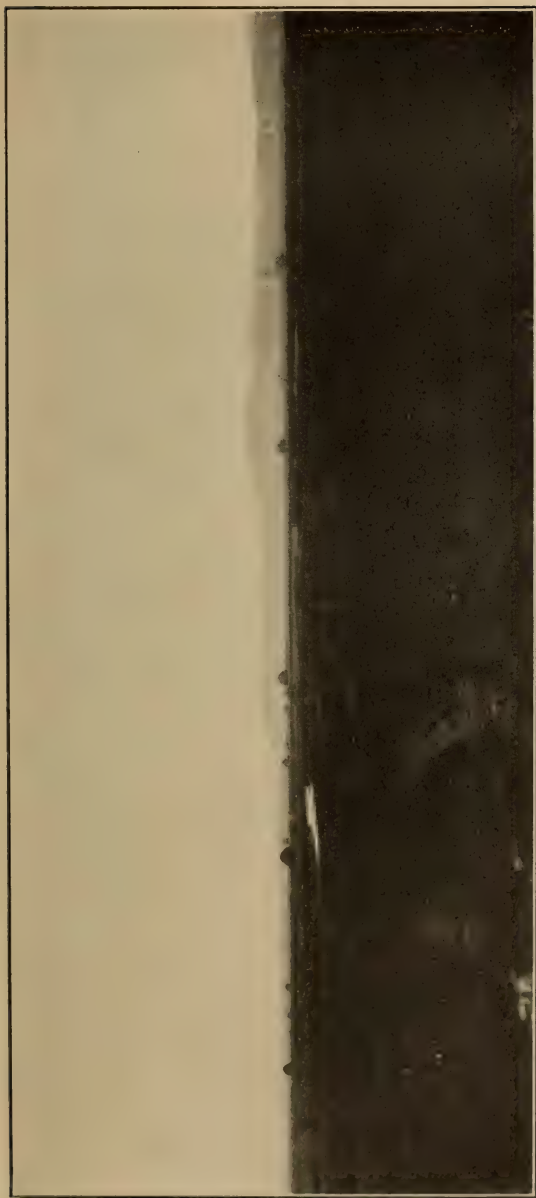


TRAP BUILT ON TOP OF OBSERVATION TOWER TO TEST AVIATION OF GIPSY-MOTH
LARVÆ. (ORIGINAL.)



SCREENS TREATED WITH TANGLEFOOT ATTACHED TO WATER TOWER TO TEST
AVIATION OF GIPSY-MOTH LARVÆ. (ORIGINAL.)

[The screen on the left-hand side is not visible in the illustration.]



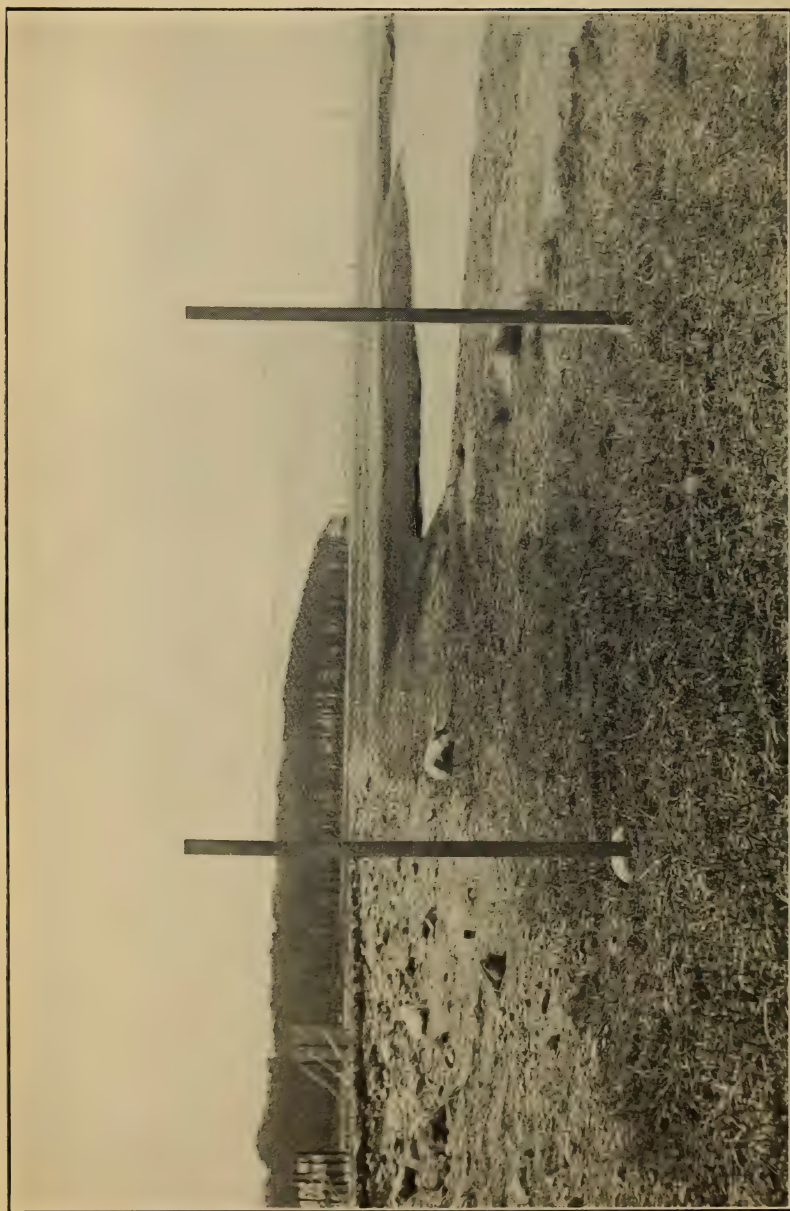
VIEW OF SALT MARSHES NEAR LYNN, MASS., WHERE EXPERIMENTS ON AVIATION OF CATERPILLARS WERE CONDUCTED.

Note that the land is level and treeless.



POST AND BOX USED IN EXPERIMENTS.

The newly hatched caterpillars spun down from the open flap of the box and were blown away by the wind. (Original.)



PORTABLE SCREENS USED FOR CATERPILLAR-AVIATION EXPERIMENTS.
Trees at Oak Island, Revere, Mass., in the background. (Original.)

covered with tanglefoot and were placed in the direction toward which the wind was blowing, the idea being that if the caterpillars were blown from the box which was set up at the central station, specimens might be caught on the screens. Owing to the variability of the air currents and the continued changes in the direction of the wind it was found better to use three screens, which were set up at distances ranging from 50 to several hundred feet from each other, but all at an equal distance from a central station. On May 6 a single screen was set up 50 feet from the central station. The wind was light and variable, but 10 minutes after it had been placed in position a caterpillar was caught. At the expiration of an hour five caterpillars were found on the screen.

It was then set up 100 feet from the central station. Four caterpillars were caught in a short time. On the following day two extra screens were made in order to provide for changes in the direction of the wind. During the day two caterpillars were caught at 150 feet, two at 200 feet, one at 250 feet, and one at 300 feet. On May 10 one caterpillar was caught at a distance of 350 feet from the central station, after the screen had been exposed for $3\frac{1}{2}$ hours. On May 11 one caterpillar was caught 500 feet from the central station, after this screen had been exposed for about an hour. The screens were then put up 600 feet from the station, and 30 minutes later two caterpillars had been caught. Two of the screens were then set up 700 feet from the station and remained there until late in the afternoon. Before leaving for the night the remaining screen was set up in the direction of the prevailing wind and at a distance, which later proved to be 1,833 feet, from the central station. On the following morning a caterpillar was found on the last-mentioned screen. The supply of first-stage caterpillars being practically exhausted on this date, we were obliged to discontinue these experiments, but the screens were removed to another point on the marsh and set up at measured distances of one-fourth mile, 1,800 feet, 2,300 feet, and 2,800 feet north of Oak Island, Revere, Mass. This is a wooded island (Pl. X) of several acres surrounded by salt marsh; the trees are generally infested with the gipsy moth, and owing to its proximity to the ocean the growth of the larvæ is considerably retarded. It was hoped that evidence might be secured that caterpillars were carried by the wind from this locality, but no larvæ were caught on the screens, although they remained in position until June 13.

In connection with these experiments it should be said that practically the whole of this salt-marsh area (Pl. IX) is flooded at high tide; hence it was possible to carry on the experiments during only a part of the day. The weather during April was cool, which is usually the case in this region near the seacoast, where the land is flat and exposed to strong air currents. The gipsy-moth caterpillars are not

very active unless the weather is warm, and when the experiments were conducted on cool days it was necessary to strike the box in which the egg clusters and caterpillars were confined in order to jar more of the larvæ from the open end and induce them to spin down toward the ground. If a strong wind was blowing at the time, they would be caught up and blown away, and occasionally it was possible to see them drift 20 or 30 feet before they passed from view. Table I gives a summary of the data secured in these experiments.

TABLE I.—*Direction and velocity of wind, at Lynn Marshes, Mass., May 6 to 12, 1910.*

Date.	Screens.		Wind.		Average temperature.	Number of larvæ caught.
	No.	Distance from station.	Direction.	Average velocity.		
1910.						
		<i>Feet.</i>		<i>Miles per hour.</i>	<i>°F.</i>	
May 6.....	1	50	NW.	11	60	5
Do.....	1	100	NW.	11	61	4
May 7.....	3	150	SW.	14 to 17	66 to 70	2
Do.....	3	200	SW.	14 to 17	66 to 70	2
Do.....	3	250	SW.	14 to 17	66 to 70	1
Do.....	3	300	SW.	14 to 17	66 to 70	1
May 10.....	3	350	SW.	18 to 23	63 to 67	1
May 11.....	3	500	SW.	15	63	1
Do.....	3	600	SW.	15	66	2
May 12.....	2	700	W.			0
Do.....	1	1,833	W.	7 to 19	51 to 66	1

The temperature records and velocity of the winds were secured through the courtesy of the United States Weather Bureau at Boston.

The notes that were kept on the marshes show that the direction of the wind varied slightly from the Weather Bureau records, and the former are given above. In other respects there were probably minor differences, but they would not affect the result to any great extent. It should be noted, however, that on none of the days mentioned did the wind maintain a velocity which was at all constant, and changes in direction were sudden and variable. This added to the difficulty in carrying on the experiments and made it necessary to change repeatedly the location of the screens. The most data were secured on May 7, and, by referring to the table, it will be noted that the weather was warmer than on any of the other days when tests were made; also the direction of the wind was more constant.

These experiments indicate that the best opportunity for the dispersion of gipsy-moth caterpillars by the wind is when the temperature is above 65° and the velocity of the wind over 15 miles an hour. They further show that the young larvæ of this insect can be carried by the wind a third of a mile from a point less than 6 feet above the ground. This being the case, there is an opportunity for extensive natural spread by the wind. It is not necessary for the velocity of the wind to remain constant, as there is doubtless much dispersion

during sudden squalls or sharp whirlwinds, provided the temperature is high enough to cause the caterpillars to become active. Early in the spring it is quite common to see papers or leaves caught up by such winds and carried several hundred feet in the air. This often results in these objects coming in contact with strong currents high above the earth and being carried many miles before falling. Undoubtedly the same thing happens when caterpillars are suspended from the trees by the silk which they spin, although absolute proof of this point is very difficult to secure. Several other elements have an important bearing on this matter, such as the density of infestation and the quantity of silk which is produced by the first-stage larvæ.

QUANTITY OF SILK PRODUCED BY FIRST-STAGE GIPSY-MOTH LARVÆ.

A record is given on page 331 of the report on the gipsy moth, by Messrs. Forbush and Fernald, of the quantity of silk produced by first-stage gipsy-moth larvæ. The data were secured by inducing the larvæ to commence spinning, after which the end of the thread was attached to a reel, and the quantity produced was determined by multiplying the circumference by the number of revolutions which it was turned. In these experiments newly hatched caterpillars produced the following quantities of silk: 4 feet 6 inches, 9 feet 7 inches, 38 feet 2 inches, and 69 feet 4 inches. Older first-stage caterpillars spun: 53 feet 2 inches, 24 feet 2 inches, 3 feet 2 inches, 6 feet 4 inches, 7 feet, 25 feet 3 inches, and 22 feet 6 inches. The record indicates that some of the caterpillars could not be induced to spin, but from the figures given the quantity of silk spun by newly hatched first-stage caterpillars ranged from 4 feet 6 inches to 69 feet 4 inches, giving an average of 30 feet 3 inches, while for caterpillars in the same stage that were a little older the record was from 3 feet 2 inches to 53 feet 2 inches, giving an average of 23 feet 8 inches.

These experiments were repeated in the spring of 1911. An attempt was made to use a reel similar to the one already mentioned, but much difficulty was experienced, even when the larvæ were placed in warm sunshine and when spinning was encouraged by using an electric fan to make a strong air current. It was found that no spinning would take place when the temperature was low. Unless the larvæ were constantly disturbed, they would climb up the threads which they had spun, and after this commenced it was difficult to induce them to spin more or to prevent them from crawling up to the attachment on the reel. The same thing occurs in nature, and it is quite common to find first-stage caterpillars suspended from the trees bearing a small mass of white material beneath the mouth cavity or partly around the first pair of legs. Close examina-

tion will show that this consists of silk which the larva has spun, and it is probable that this adds to the buoyancy of the insect if it is caught up by the wind.

As the method of using the reel gave very poor results, two sets of experiments were carried on by Mr. C. W. Stockwell in the laboratory. He induced the caterpillars to spin, and attached the thread to the end of a stick 1 yard long. As the insect lowered itself, the thread was measured with the stick by raising and inverting it, and thus the larva was prevented from spinning to the floor of the room. In the first set records were secured from 18 newly hatched larvæ that had not fed. The quantity of silk spun ranged from 7 feet 6 inches to 25 feet 6 inches, averaging 17 feet. Fourteen records were then secured from larvæ 3 days old, and the silk ranged from 12 feet to 63 feet 5 inches, with an average of 31 feet.

The results of these tests show that there is much individual variation in the quantity of silk that caterpillars will spin, and it is probable that under favorable outdoor conditions much more would be produced than is indicated by the averages given.

If 20 to 30 feet of silk is spun by a larva it will undoubtedly help it to remain in the air in case the thread is broken by the wind, and will probably add buoyancy to the insect and thus increase the distance that would ordinarily be covered by wind spread.

RELATION OF TEMPERATURE TO HATCHING OF EGGS.

Temperature has a very important relation to the hatching of insect eggs; hence the time of larval appearance varies from year to year. Gipsy-moth eggs begin to hatch the last week in April, but the hatching is often deferred a week or more. Owing to the warm weather in March, 1910, hatching took place in the field as early as April 3, but the bulk of the eggs did not hatch until much later. In the case of the gipsy moth—and the same principle governs in the case of other insects which winter in the egg form—it is possible to secure hatching in the winter if the eggs are kept in a warm room. The length of the period of high temperature which is required to hatch them varies with the season of the year. For example, gipsy-moth eggs collected late in December and kept at a temperature of from 70° F. to 80° F. will hatch in about 15 days, while if the same collection is made in March hatching will take place in about half the time. This shows that as the normal time for hatching approaches it requires a shorter period of warm weather to bring out the larvæ.

During the past four years the first date of finding gipsy-moth larvæ in the field in Massachusetts was, in 1908, April 22; 1909, April 22; 1910, April 3; 1911, April 28. The data for 1908 were furnished by Mr. W. F. Fiske. The other dates were secured from field reports

made to Mr. D. M. Rogers. The hatching thus recorded took place in localities which became warm very early in the spring, but this serves as a basis for comparing the temperatures.

The entire period of hatching usually extends over a month. In fact, in some parts of the infested territory where the summer season is short, owing to the high altitude or to the northern latitude, the period is considerably longer.

Mr. Henry L. McIntyre, one of the general foremen in charge of moth work for the Bureau of Entomology, informs me that several unhatched gipsy-moth egg clusters were found July 1, 1910, at Winchendon, Mass., by scouts who were working under his direction. The clusters were well formed and were apparently fertile, although this point was not fully determined.

He also reports that in the spring of 1908 he found egg masses in maple swamps near Portsmouth, N. H., that had not hatched on June 15. In 1909 he observed several egg clusters that had just hatched in a stone wall at Gilford, N. H., on June 4.

This shows the variation in time of hatching in different localities and situations, but it is exceptional for hatching to take place after June 1. Additional data on the dates of hatching have been furnished by Mr. F. A. Bates, who has for many years been prominently connected with moth work, and from various other careful observers.

The accompanying diagram (fig. 1) shows the range in temperatures for 20 days preceding and 10 days following the first report of hatching for the years 1908 to 1911. It will be noted that in 1910, when hatching was recorded April 3, nearly two weeks of warm weather immediately preceded hatching. In 1909 the warm weather was interrupted by several cold days, while in 1908 and 1911 hatching took place during the only warm period that occurred in the month. This last record shows the tendency of the eggs to hatch at the first opportunity as the season grows late.

EFFECT OF TEMPERATURE ON ACTIVITY OF LARVÆ.

As the activity of the caterpillars after hatching as well as their emergence from the eggs depends upon the temperature, several experiments were made to determine the temperature at which the larvæ are most active, since it is obvious that little distribution by wind would be possible unless the larvæ were active during the first stage. Accordingly, a series of laboratory tests were made by Mr. Collins. For this purpose a constant-temperature incubator was used, it being arranged in such a way that the thermostat which regulated the heat supplied by electric incandescent lamps could be changed without opening the incubator.

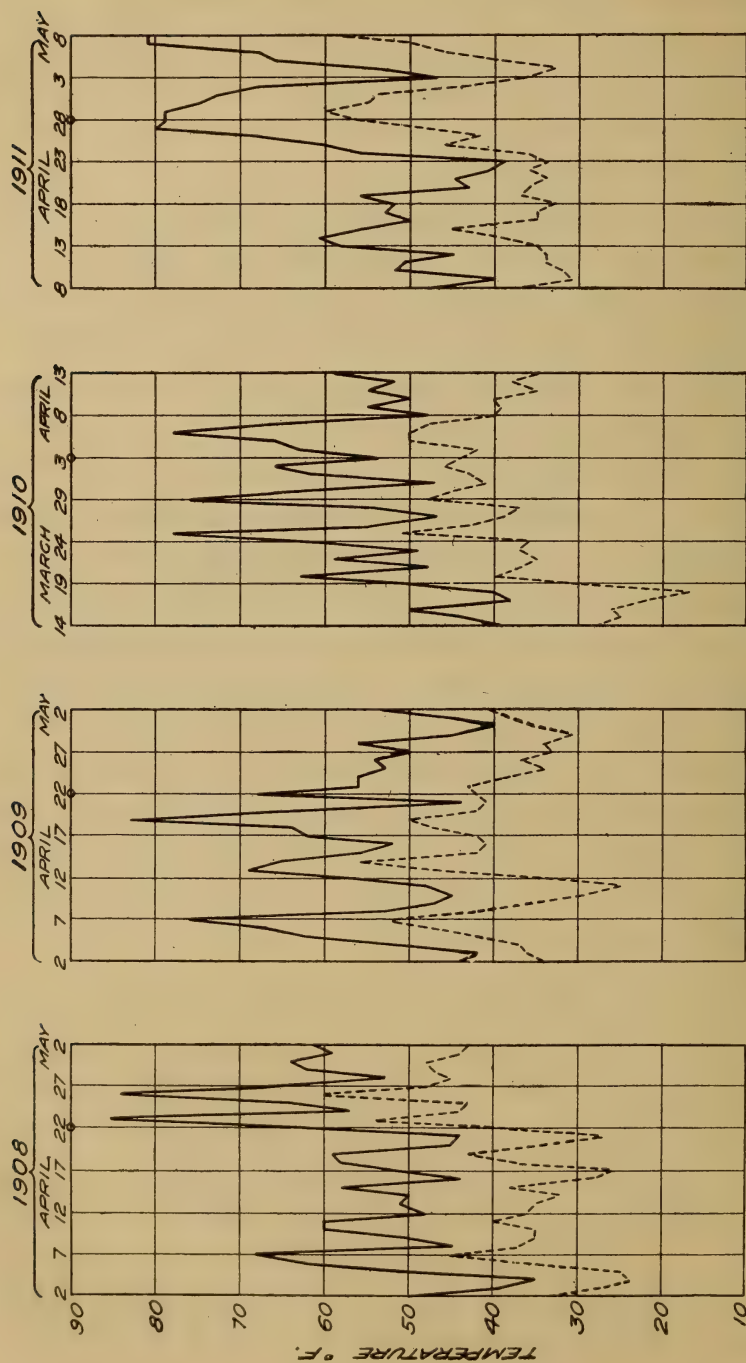


FIG. 1.—Diagram showing maximum and minimum temperature before and after hatching of eggs of the gipsy moth, 1908–1911. (Original.)

LABORATORY EXPERIMENTS.

On May 3, 1911, 1,500 gipsy-moth caterpillars, 12 hours old or less, were placed in a glass battery jar, which in turn was placed for a short time in the laboratory yard where the temperature was 46° F. There was no activity, and later, when the jar was placed in the basement where the temperature was 48° to 50° F., the same result was observed. The jar was then placed in the incubator and the following notes were made by Mr. Collins:

The temperature was held at degrees mentioned for from 10 to 20 minutes.

52° F. No motion unless larvæ were disturbed; then it was very slight.

54° F. No motion in mass of larvæ. Two crawled 5 inches.

56° F. No motion in mass of larvæ.

58° F. No motion in mass of larvæ. Two have crawled 1 inch in 10 minutes.

60° F. No motion in mass of larvæ. Two have crawled 6 inches; two, 4 inches.

62° F. No motion in mass of larvæ. Fifteen larvæ crawling. One climbing up thread that had been spun. One spun 1 inch and crawled up. One spun $\frac{1}{2}$ inch.

64° F. Motion in mass noticeable. Fifty larvæ crawled actively, a few spinning.

66° F. Motion in mass more noticeable. One hundred larvæ crawling, a few spinning short threads.

68° F. Mass of larvæ active. Eight larvæ have each spun $7\frac{1}{2}$ inches.

70° F. Almost every larva moving.

72° F. Caterpillars all crawling about and spreading freely.

74° F. Many spinning and hanging by threads.

76° F. Larvæ very active and spinning.

78° F. Half of the larvæ have crawled from jar. All active. They spin rapidly.

80° F. Active and spinning freely.

84° F. About the same as 80° F.

88° F. Possibly a little more active.

92° F. Larvæ crawling and spinning more rapidly.

96° F. All caterpillars have left the jar and are on the move. It took this temperature to force all of them from the jar.

100° F. Larvæ very active. They crawl very fast, but spin little.

106° F. Same as 100° F.

108° F. Larvæ gathered in masses; less crawling and spinning.

110° F. Little crawling; larvæ squirming in the masses.

After holding the temperature for two hours at 110° F. the incubator was cooled down to 82° F. Twenty-five dead larvæ were found, and the remainder were not very active. The temperature was then raised again to 110° F. At 92° F. larvæ became more active, and this continued until 100° F. was reached. Most of them showed the effects of the previous high temperature.

A set of observations was also made May 3, 1911, on first-stage caterpillars which hatched April 22 and were feeding in trays at the laboratory. No motion was noted at 54° F., but when the temperature rose to 62° F. they crawled slowly about on the food. At 68° F. they were crawling freely, and activity increased as the temperature rose.

On May 6 a large tray of caterpillars was placed in a room in direct sunlight and the temperature rose to 100° F. This resulted in abnormal activity, and many of the larvæ spun a considerable quantity of silk.

In order to check these experiments, Mr. Collins made a series of field observations in woodland in Melrose, Saugus, and Reading.

FIELD OBSERVATIONS.

May 13, 1911, visited woods east of the laboratory at Melrose Highlands, which had been badly infested and partially to wholly defoliated in 1909 and 1910. Infestation not as bad this year. At 9.30 a. m. the temperature in the sun was 92° F.; in the shade, 84° F.

All eggs have apparently hatched, and the caterpillars are in the first stage. There is plenty of foliage. Very little spinning was observed. In the afternoon of the same day visited badly infested woods in Saugus. Temperature, 96° F. in sun; 84° F. in shade. A strong wind was blowing, which varied from northwest to southwest. First-stage caterpillars were spinning some. If a branch was shaken, they would spin down and be blown away.

On the following day observations were made at Reading, Mass. The temperature ranged from 85° F. in the sun to 79° F. in the shade; the wind was west and southwest, but rather cool. First-stage caterpillars were feeding steadily and spinning freely. Twenty very small first-stage larvæ and two that were nearly ready to molt were observed spinning down from a white-oak tree. Threads from 2 to 4 feet long were noted, but it was very difficult to determine the quantity of silk spun, as it is almost invisible. A considerable quantity of silk was noticed among the small twigs and branches on this tree, therefore it is evident that frequent spinning had been attempted by the larvæ.

Although few field observations were made to determine the temperature at which gipsy-moth caterpillars are active, it is evident that the results do not vary greatly from those carried on in the laboratory. Experiments show that there is practically no activity when the temperature is below 60° F., and that only a part of the caterpillars move about at 65° F. Above this point activity increases rapidly.

RELATION OF ACTIVITY TO THE SPINNING OF SILK.

The above experiments show that the activity of the caterpillars is governed by the temperature, and it is obvious that the spinning of silk depends largely upon the activity of the larvæ, and hence upon the temperature. There are other factors, however, that enter into the problem, and these must be considered with the element of temperature. They are:

Location where eggs are deposited.
Degree of infestation.
Kind of food plants.

Condition of food plants.
Direction and character of the wind.

LOCATIONS WHERE EGG CLUSTERS ARE DEPOSITED.

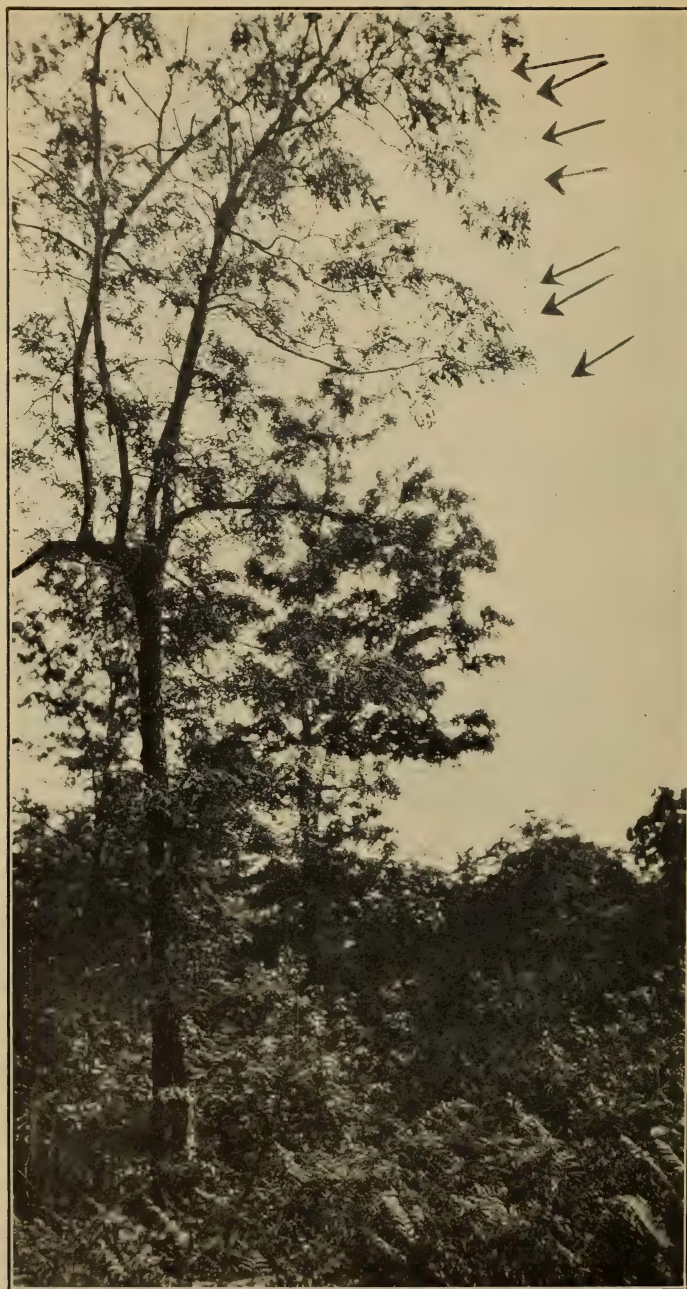
The egg clusters of the gipsy moth are not always deposited on the plant which furnishes the food for the previous generation. In fact, when the caterpillars are nearly ready to transform they usually



FIG. 1.—FEMALE GIPSY MOTHS DEPOSITING EGG CLUSTERS ON WHITE-OAK TREE NEAR THE GROUND. (ORIGINAL.)



FIG. 2.—EGG CLUSTERS ON STONE WALL. LOCATION OF CLUSTERS INDICATED BY ARROW. (ORIGINAL.)



OAK TREE SHOWING GIPSY-MOTH CATERPILLERS SPINNING TO THE GROUND. POSITION OF LARVÆ INDICATED BY ARROWS.

Note that the tree is partially defoliated. (Original.)



SOLID WHITE-PINE BLOCK NEAR NASHUA, N. H.

Small trees in foreground were transplanted some years ago. The foliage of this species is not attacked by *small gipsy-moth* larva, so it is not injured if grown in clean stands. (Original.)

seek places which are protected from the sun, and in such situations pupation takes place. The egg masses are deposited near the cases from which the females emerged. Hence it is seldom possible to find egg clusters on the upper sides of the branches or twigs of trees, because the lower sides furnish more protection and they are sought by the caterpillars before pupating. For this same reason it is usually possible to find many egg clusters on tree trunks just above the ground (Pl. XI, fig. 1), especially if there is grass or other material which would furnish protection. Many larvæ, however, crawl from the trees and seek secluded places, sometimes at a considerable distance from their food plants, and rubbish piles, stone walls (Pl. XI, fig. 2), lumber piles (Pl. III), outbuildings, or other protected places are often found badly infested with egg clusters.

The larvæ which hatch in such situations must of necessity find suitable food if they are to survive, and the more traveling it is necessary for them to do to accomplish this purpose the greater chance there is that dispersion by the wind will take place. For instance, egg clusters are frequently depos-

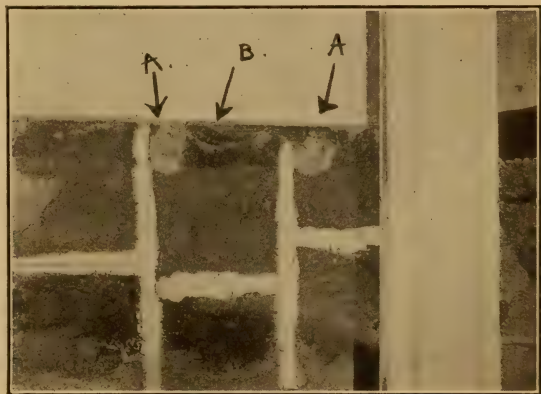


FIG. 2.—Female pupal case and egg clusters of gipsy moth on stone foundation under woodwork of house. Arrows A indicate location of egg clusters; arrow B indicates location of pupal case. (Original.)

ited beneath porches or on the underpinning of houses (fig. 2), where it is impossible to destroy them without first removing a part of the building. After hatching takes place the larvæ can commonly be found wandering about in search of food.* They often crawl to the roofs of the buildings, and if they spin down from such a location, which often happens, there is ample opportunity for dispersion by the wind.

As a rule the location of the egg clusters and the distance that the larvæ have to travel for food are important factors, because hunger causes them to search for food, and activity is essential to dispersion.

DISTANCE FIRST-STAGE LARVÆ CAN CRAWL.

It is important to know how far first-stage larvæ can crawl, as upon this factor depends the chance for the establishment of many new colonies. Experiments reported by Forbush and Fernald show that newly hatched larvæ have crawled from 36 to 144 feet before

dying. The tests were carried on under laboratory conditions which were unfavorable to the insects.

During the winter of 1911-12 a few experiments of the same sort were tried at the gipsy-moth parasite laboratory, and records ranging from 31 to 138 feet have been secured. The conditions for making the tests were very unsatisfactory, and it is probable that newly hatched larvæ, without food, would be able to crawl, on the average, about 100 feet in the open before death would ensue. This does not give the maximum distance that the majority of larvæ could crawl, because many of them in going that distance would find some foliage which could be eaten and thus would be enabled to proceed farther.

DEGREE OF INFESTATION.

The degree of infestation has an important bearing on dispersion. When only a few egg clusters are present on a tree the larvæ have plenty of food, and it is not necessary for them to move about so actively. As the infestation increases the feeding conditions become more crowded, and, as a result, the larvæ are disturbed and large numbers of them spin to the ground. In badly infested places the air is sometimes well filled with a network of silken threads, which are made by larvæ spinning to the ground (Pl. XII), and it is possible to see large numbers of them hanging from the trees.

These conditions favor dispersion by the wind.

KINDS OF FOOD PLANTS.

At the time the gipsy moth first became noticeable in this country and caused so much damage, it seemed almost impossible to find plants upon which it would not feed. Many experiments were carried on with fifth and sixth stage caterpillars, which were fed in glass jars upon various kinds of foliage, and very few plants were rejected, especially if the insects were supplied with no other food. The results of these experiments were published by Forbush and Fernald in 1896. Since that time it has become gradually more noticeable that the larvæ show marked preference for certain species of trees. This may be due to a gradual change of habit, or to the fact that caterpillars which do not find food which is most suitable, although they may strip and injure the tree, may not come through to maturity.

There is considerable difference in food requirements of the small and the large caterpillars of this insect, the former not being able to survive on some species of trees upon which the larger ones will feed. The white pine is one of the trees of which this may be said, and it has been repeatedly demonstrated that the first-stage larvæ can

not live upon this tree. This being the case, dispersion by the wind, which is concerned chiefly with small caterpillars, is limited in its results by the food plants which the young caterpillars are able to reach, and this depends somewhat upon the ability of the larvæ to crawl. For instance, if caterpillars are blown by the wind and drop on cultivated ground or in pastures, they must perish on account of scarcity of food. Similarly, if caterpillars lodge in solid pine forests (Pl. XIII) they will perish for want of suitable food. In fact, the establishment of the pest in this way depends upon the larvæ being able to find suitable food. Either the larvæ must be dropped by the wind on a food plant that is favorable for their development or they must fall within crawling distance of it. In many sections of the country the foliage is unfavorable for gipsy-moth food; hence colonies have not become established.

CONDITION OF FOOD PLANTS.

The condition of the trees in an infested area has an important relation to the liability of the spread of the insect. Unfavorable food, coupled with warm weather, naturally stimulates the activity of the larvæ, and this increases the chances for spread. If there are dead trees in the infested area the chances of wind spread of the larvæ from them are greater than on healthy trees, as the caterpillars are unprotected from the sun and wind and move about continually in search of food if the temperature is high enough.

DIRECTION AND VELOCITY OF THE WIND.

Of all of the factors thus far enumerated perhaps no one is as important with regard to dispersion as is the wind. The others may be regulated or controlled to some extent but it is impossible to do this with the wind. For instance, it is possible to reduce the infestation in any area so that wind spread is nearly precluded, because it is dependent upon the factors which have been mentioned, which, with the exception of temperature, can be controlled.

The natural trend of dispersion of the gipsy moth has been toward the north and northeast. The spread of the brown-tail moth has been chiefly in a northeasterly direction, and the reason attributed to this has been that the prevailing wind during July, when the moths are flying, was from the opposite direction. Since the aviation of first-stage gipsy-moth larvæ has been proved, it is evident that a part, at least, of the more newly infested area is due to the action of the wind. It is also true that the prevailing winds in April and May, when the larvæ are small enough to be distributed in this way, is chiefly from the south and southwest. Table II gives the record of wind direction for 20 days in April and May, when the temperature

was highest, during the years 1902 to 1911. Table III shows the wind direction during the same number of days for the lowest of the maximum temperatures.

TABLE II.—*Direction of wind during 20 days of highest temperature in April and May, 1902-1911. (From records of the United States Weather Bureau at Boston, Mass.)*

Date.	Temperature.	Direction of wind.	Date.	Temperature.	Direction of wind.
	°F.			°F.	
Apr. 22, 1908.....	85	SW.	May 22, 1911.....	92	W.
Apr. 26, 1908.....	84	SW.	May 23, 1902.....	88	SW.
Apr. 29, 1903.....	83	W., NW.	May 18, 1903.....	88	W.
Apr. 30, 1903.....	83	S.	May 19, 1903.....	88	SW.
Apr. 19, 1909.....	83	SW.	May 27, 1908.....	88	SW.
Apr. 27, 1911.....	80	W.	May 29, 1911.....	88	SW.
Apr. 28, 1911.....	79	W.	May 26, 1904.....	87	SW.
Apr. 29, 1911.....	79	NW., SE.	May 26, 1908.....	87	SW.
Apr. 6, 1910.....	78	SW.	May 21, 1911.....	87	SW.
Apr. 7, 1909.....	76	SW.	May 19, 1906.....	86	W.
Apr. 29, 1902.....	75	S., W.	May 31, 1908.....	86	SW.
Apr. 30, 1911.....	75	SW.	May 24, 1910.....	86	SW.
Apr. 26, 1905.....	74	W.	May 28, 1911.....	86	SW.
Apr. 30, 1907.....	73	SW.	May 24, 1904.....	85	SW.
Apr. 15, 1910.....	73	NW.	May 11, 1911.....	85	SW.
Apr. 21, 1905.....	72	SW.	May 24, 1902.....	84	SW.
Apr. 30, 1905.....	72	W.	May 17, 1903.....	84	SW.
Apr. 6, 1911.....	72	W.	May 21, 1903.....	84	SW., NW.
Apr. 23, 1902.....	71	E., SW.	May 22, 1903.....	84	NW.
Apr. 28, 1902.....	71	W.	May 12, 1908.....	84	SW.

TABLE III.—*Direction of wind during 20 days of lowest temperature in April and May, 1902-1911. (From records of the United States Weather Bureau at Boston, Mass.)*

Date.	Temperature.	Direction of wind.	Date.	Temperature.	Direction of wind.
	°F.			°F.	
Apr. 4, 1908.....	35	NW.	May 2, 1903.....	44	E., SE.
Apr. 2, 1911.....	35	W.	May 3, 1907.....	44	E.
Apr. 7, 1907.....	36	E.	May 1, 1909.....	45	NE.
Apr. 5, 1903.....	37	NW.	May 7, 1908.....	46	E.
Apr. 20, 1904.....	38	N., W.	May 3, 1903.....	47	E.
Apr. 2, 1906.....	38	N.	May 17, 1905.....	47	NE.
Apr. 8, 1907.....	38	E.	May 22, 1909.....	47	NE.
Apr. 9, 1907.....	39	N.	May 5, 1910.....	47	N.
Apr. 10, 1910.....	39	W.	May 3, 1911.....	47	W.
Apr. 3, 1908.....	39	W., NW.	May 28, 1906.....	48	NE.
Apr. 4, 1911.....	39	SE.	May 2, 1907.....	49	NE.
Apr. 23, 1911.....	39	NE.	May 4, 1907.....	49	SE.
Apr. 16, 1903.....	40	NE.	May 7, 1907.....	49	E.
Apr. 16, 1904.....	40	NW.	May 27, 1907.....	49	E.
Apr. 2, 1907.....	40	N.	May 8, 1908.....	49	NE.
Apr. 30, 1909.....	40	NE.	May 4, 1910.....	49	NE.
Apr. 1, 1911.....	40	W.	May 3, 1902.....	50	NE.
Apr. 9, 1911.....	40	N.	May 15, 1904.....	50	NE.
Apr. 10, 1902.....	41	N.	May 16, 1905.....	50	N., NE.
Apr. 9, 1906.....	41	SE.	May 11, 1906.....	50	W.

A glance at these tables indicates that in April, when the temperature ranged above 70°, 16 days out of 20 the wind varied between south and west. For the same month during the low temperatures the wind ranged between north and east for 10 days out of the 20. Corresponding figures during May show that for 18 days out of 20 the wind was from the south and west, and for 16 days out of 20

the wind was from north to east. For the years mentioned, when there were bad woodland infestations in Massachusetts, the wind during the hot days was usually southwest, which would be most favorable for the spread of the insect into the region where it has since been found in scattered colonies.

The relation of temperature and the direction and velocity of the wind are intimate, as shown by the tables which follow.

It has been stated that wind spread is possible when the temperature as recorded by the Weather Bureau is as low as 65°, but an increase in temperature makes the chances of spreading greater. Tables IV and V give the direction of the wind for the different years, at the Boston Weather Bureau station when the temperature was 65° or higher, and the wind velocity 10 miles per hour or more.

In all cases where the temperature is 70° F. or above, italic letters and figures are used in the columns of the table giving the temperature and the direction and velocity of the wind. Otherwise the letters and figures are in Roman.

TABLE IV.—*Temperature and direction and velocity of wind on dates after hatching of gipsy-moth caterpillars, 1902–1911.*

(Data from U. S. Weather Bureau at Boston, Mass.)

Date.	24 hours.	Maximum temperature.	Direction of wind.	Velocity of wind.	Date.	24 hours.	Maximum temperature.	Direction of wind.	Velocity of wind.
		° F.		<i>Miles per hour.</i>			° F.		<i>Miles per hour.</i>
1902.					1902.				
Apr. 21	AM.....	65	W.....	12	May 16	AM, PM.....	72	W.....	20
23	PM, AM.....	71	W.....	29	17	AM.....	70	N.....	18
24	AM.....	66	W.....	26	18	AM, PM.....	78	NW.....	14
26	AM.....	67	SW.....	32	21	AM.....	72	S W.....	16
28	AM, PM.....	71	NW.....	18	22	AM, PM.....	80	S W.....	23
29	AM, PM.....	75	S.....	26	23	AM, PM.....	88	S W.....	19
May 5	AM.....	69	SW.....	19	24	AM, PM.....	84	S W.....	24
7	AM, PM.....	73	S.....	20	25	AM, PM.....	76	S W.....	24
8	AM, PM.....	72	S W.....	26	26	AM, PM.....	80	S W.....	26
9	AM.....	65	W.....	38	27	AM.....	71	S.....	20
13	AM.....	67	N.....	19	30	AM.....	69	W.....	33
14	AM.....	65	W.....	14	31	AM.....	65	SW.....	17

NOTE.—During the years 1902, 1903, and 1904 the Boston Weather Bureau did not record temperature hourly, but took readings at 8 am and 8 pm each day. AM in the table refers to the reading made at the period from 8 am to 8 pm, while PM covers the following 12 hours. The direction of the wind and its maximum velocity did not necessarily occur when the temperature was at the maximum, for the temperature may have been 65° or even less at that time.

Date.	24 hours.	Temperature.	Direction of wind.	Velocity of wind.
		° F.		<i>Miles per hour.</i>
1903.				
Apr. 28	AM.....	66	S.....	13
29	AM, PM.....	83	NW.....	19
30	AM.....	83	S W.....	28
May 10	AM.....	75	S.....	19
11	AM.....	69	S.....	13
12	AM.....	70	S.....	13
13	AM.....	74	S.....	20
14	AM.....	70	E.....	18
15	AM.....	67	SE.....	10

TABLE IV.—*Temperature and direction and velocity of wind, etc.*—Continued.

Date.	24 hours.	Temperature.	Direction of wind.	Velocity of wind.
		° F.		Miles per hour.
1903.				
May 17	AM, PM	84	SW	19
18	AM, PM	87	NW	15
19	AM, PM	88	SW	16
20	PM, AM	80	W	16
21	AM, PM	84	S, SW	18
22	AM, PM	84	NW	21
23	AM	67	NW	27
26	AM	68	S	22
27	AM, PM	73	SW	23
28	AM, PM	75	SW	27
29	AM, PM	79	N	18
30	AM	67	N	18
1904.				
Apr. 10	AM	65	SW	19
25	AM	68	NW	14
30	AM	70	SW	14
May 3	AM	65	SW	15
4	AM, PM	80	S	20
5	AM, PM	82	W	23
7	AM, PM	81	SW	22
8	AM, PM	78	SW	25
10	AM	72	E	18
11	AM	66	E	15
12	AM	65	SE	10
17	AM	68	SW	19
20	AM	69	W	18
21	AM, PM	77	S, SW	17
22	AM, PM	81	S	24
23	AM, PM	78	S	27
24	AM, PM	84	W	16
25	PM, AM	74	SW	24
26	AM, PM	87	SW	21
27	AM	82	NW	25
28	AM, PM	75	W	23
29	AM, PM	80	SW	24
30	AM, PM	72	SW	22
31	AM	65	SE	13
1905.				
Apr. 10	11 a. m. to 6 p. m.	66 to 70	SW	14 to 28
20	10 a. m. to 4 p. m.	65 to 70	SW	14 to 25
21	11 a. m. to 5 p. m.	66 to 72	SW	11 to 18
26	10 a. m. to 7 p. m.	68 to 74	SW	12 to 25
30	1 to 5 p. m.	66 to 72	W, NW	11 to 13
May 3	4 to 7 p. m.	72 to 76	SW	16 to 26
6	8 a. m. to 11 p. m.	65 to 79	SW	11 to 26
7	7 a. m. to 8 p. m.	66 to 83	W, NW	12 to 27
8	3 to 5 p. m.	65 to 67	SE, SW	13 to 18
9	11 a. m. to 2 p. m.	65 to 66	NW	20 to 27
10	1 to 5 p. m.	66 to 68	NW	12 to 18
11	10 a. m. to 2 p. m., 4 to 8 p. m.	65 to 77	SW	10 to 19
19	10 a. m. to 6 p. m.	65 to 68	W	14 to 18
22	11 a. m. to 4 p. m.	66 to 71	W	11 to 14
24	4 to 6 p. m.	65 to 66	SE	13 to 14
25	9 a. m. to 6 p. m.	67 to 74	SW	15 to 19
26	7 a. m. to 10 p. m.	65 to 78	SW	14 to 35
27	2 to 7 p. m., 9 to 10 p. m.	67 to 75	SW	10 to 13
28	10 a. m. to 5 p. m.	78 to 82	NW	10 to 12
29	8 a. m. to 9 p. m.	70 to 83	W, SW	10 to 14
30	4 to 5 p. m.	70	NW	10
1906.				
Apr. 27	1 to 6 p. m.	66 to 69	W	10 to 17.
29	4 to 6 p. m.	65 to 66	SW	12 to 14.
30	11 a. m. to 12 m.	66	SW	18.
May 1	12 m. to 6 p. m.	66 to 68	NW	15 to 18.
2	1 to 3 p. m.	65 to 67	SW	10 to 17.
3	7 a. m. to 2 p. m.	66 to 70	NW	16 to 28.
4	1 to 2 p. m.	65	SW	12.
5	8 a. m. to 12 m.	68 to 71	SW	10 to 17.
9	11 a. m. to 3 p. m.	65 to 67	SE, S	22 to 37.
12	12 m. to 4 p. m., 11 p. m. to 12 p. m.	65 to 69	SW	11 to 25.
13	4 a. m. to 8 p. m.	65 to 83	SW, NW	12 to 27.
15	3 to 4 p. m.	65	SE	10.
18	2 to 3 p. m., 10 to 11 p. m.	75 to 78	SE, SW	10.
19	12 p. m. to 4 a. m., 7 a. m. to 11 p. m.	65 to 86	SW, NW	10 to 18.
22	1 to 5 p. m.	68 to 70	SW	13 to 16.

TABLE IV.—Temperature and direction and velocity of wind, etc.—Continued.

Date.	24 hours.	Temperature.	Direction of wind.	Velocity of wind.
		° F.		Miles per hour.
1906.				
May 26	12 m. to 12 p. m.	66 to 81	SW	12 to 27.
27	12 p. m. to 2 a. m., 7 a. m. to 3 p. m.	65 to 75	SW	10 to 15.
30	12 m. to 6 p. m.	65 to 68	NW	11 to 15.
31	10 a. m. to 8 p. m.	65 to 75	SW	10 to 13.
1907.				
Apr. 25	11 a. m. to 5 p. m.	65 to 70	SW	14 to 30.
29	4 to 6 p. m.	65 to 68	SW	16.
30	9 a. m. to 6 p. m.	65 to 73	SW	13 to 25.
May 10	9 a. m. to 6 p. m.	66 to 72	SW	12 to 32.
13	10 a. m. to 6 p. m.	65 to 75	SW	20 to 30.
16	8 a. m. to 5 p. m.	65 to 74	SW	10 to 19.
18	7 to 11 p. m.	65 to 70	SW	10 to 14.
19	2 to 7 p. m.	69 to 81	SW	10 to 17.
20	11 a. m. to 2 p. m.	65 to 67	SW, NW	10 to 19.
1908.				
Apr. 23	9 a. m. to 8 p. m.	70 to 85	SW	11 to 20.
26	7 a. m. to 12 p. m.	66 to 84	SW	10 to 18.
May 11	10 a. m. to 11 p. m.	66 to 81	SW	10 to 17.
12	12 p. m. to 1 a. m., 7 a. m. to 12 p. m.	69 to 84	SW	10 to 30.
13	12 p. m. to 12 m.	70 to 75	SW, NW	11 to 18.
16	4 to 6 p. m.	65 to 68	SE, S.	15 to 16.
17	8 a. m. to 4 p. m.	65 to 75	SW	12 to 16.
19	12 m. to 8 p. m.	65 to 75	S.	10 to 17.
23	4 p. m. to 12 p. m.	66 to 77	SE, SW	10 to 14.
24	12 p. m. to 10 a. m., 12 m. to 1 p. m., 11 p. m. to 12 p. m.	65 to 78	SW, NW	10 to 13.
26	7 a. m. to 12 p. m.	66 to 87	SW	10 to 27.
27	12 p. m. to 7 p. m., 9 to 10 p. m.	69 to 88	SW, W	10 to 18.
29	11 a. m. to 12 p. m.	65 to 80	SW	10 to 13.
30	1 to 3 a. m., 1 to 2 p. m.	65 to 66	SW	11 to 12.
31	2 a. m. to 11 p. m.	65 to 86	SW	10 to 19.
1909.				
Apr. 22	2 to 6 p. m.	66 to 68	SW	11 to 13.
May 6	8 a. m. to 4 p. m.	68 to 83	SW, NW	11 to 17.
10	8 a. m. to 7 p. m., 8 to 10 p. m.	65 to 76	SW	11 to 27.
11	10 a. m. to 4 p. m.	66 to 72	NW	10 to 22.
12	10 a. m. to 8 p. m.	65 to 73	NW	11 to 21.
13	8 to 9 a. m., 11 a. m. to 9 p. m.	65 to 77	SW	10 to 19.
14	12 m. to 7 p. m.	76 to 81	SW, NW	11 to 14.
15	7 a. m. to 1 p. m.	65 to 74	NW	10 to 15.
24	3 to 8 p. m.	65 to 74	NW	12 to 13.
26	11 a. m. to 8 p. m.	66 to 76	SW	10 to 17.
27	12 m. to 4 p. m.	65 to 69	SE	15 to 17.
30	8 to 9 a. m., 12 m. to 7 p. m.	65 to 70	NW	14 to 25.
31	7 a. m. to 11 p. m.	66 to 80	NW	11 to 20.
1910.				
Apr. 6	10 a. m. to 7 p. m.	65 to 78	SW	10 to 13.
7	11 a. m. to 2 p. m.	65 to 67	SW, NW, W	10 to 13.
14	12 m. to 7 p. m.	65 to 69	W, NW	10 to 17.
15	11 a. m. to 5 p. m.	66 to 73	NW	11 to 15.
19	5 to 6 p. m.	66 to 67	SE	12.
20	2 to 4 p. m.	66 to 68	SW	17 to 18.
27	12 m. to 6 p. m.	66 to 69	SW, NW	11 to 14.
30	3 to 6 p. m.	66	SW	10 to 12.
May 7	11 a. m. to 8 p. m.	65 to 70	NW, W	10 to 17.
8	11 a. m. to 3 p. m.	66 to 76	SW	10 to 18.
10	12 m. to 6 p. m.	65 to 68	NW	15 to 27.
11	12 m. to 3 p. m.	65 to 66	W	13 to 19.
17	2 to 8 p. m.	66 to 71	SE	10 to 12.
18	10 to 11 a. m.	65	SW	18.
19	1 to 6 p. m.	65 to 68	NW	17 to 26.
20	3 to 7 p. m.	68 to 76	SW	10 to 14.
23	12 m. to 7 p. m.	65 to 75	SW	10 to 15.
24	4 to 5 a. m., 7 to 10 a. m., 12 m. to 11 p. m.	65 to 86	SW	10 to 17.
25	12 p. m. to 3 a. m., 6 a. m. to 8 p. m.	65 to 74	SW	12 to 17.
26	11 a. m. to 7 p. m.	68 to 76	SW, NW	11 to 14.
27	12 m. to 1 p. m.	65	W	11.
28	12 m. to 1 p. m.	66	NW	12.
29	12 m. to 1 p. m.	65	SE	10.
1911.				
Apr. 26	3 to 5 p. m.	65 to 68	SE, SW	10 to 17.
27	8 to 10 a. m., 12 m. to 9 p. m.	65 to 80	SW	10 to 15.
28	12 m. to 1 p. m., 7 to 8 p. m.	74 to 79	SE, SW	10 to 11.
29	12 p. m. to 1 a. m., 5 to 7 p. m.	65 to 76	SW	10 to 11.
30	8 a. m. to 4 p. m.	65 to 75	SW	11 to 28.

TABLE IV.—*Temperature and direction and velocity of wind, etc.—Continued.*

Date.	24 hours.	Temperature.	Direction of wind.	Velocity of wind.
1911.				<i>Miles per hour.</i>
May 1	12 m. to 6 p. m.	° F. 66 to 72	SW	11 to 13.
2	8 a. m. to 12 m.	65 to 68	W	14 to 18.
5	2 to 3 p. m.	65	SW	10.
6	12 m. to 6 p. m.	65 to 68	SE	11 to 17.
7	9 a. m. to 4 p. m.	72 to 81	W, NW	10 to 14.
8	12 m. to 8 p. m.	66 to 81	SW	10 to 17.
9	1 to 2 p. m.	70	SW	12.
10	7 a. m. to 4 p. m.	67 to 72	NW	11 to 25.
11	9 a. m. to 12 p. m.	69 to 84	SW	11 to 25.
12	12 p. m. to 8 p. m.	67 to 81	SW	10 to 19.
13	9 a. m. to 7 p. m.	68 to 80	W, NW	13 to 18.
15	10 a. m. to 6 p. m.	65 to 73	SW	10 to 19.
16	9 a. m. to 1 p. m.	69 to 75	NW	10 to 15.
17	5 to 7 p. m.	66 to 71	SE, SW	10 to 14.
18	8 to 11 a. m., 4 to 5 p. m.	69 to 82	W	10.
21	12 m. to 12 p. m.	70 to 87	SW	11 to 14.
22	12 p. m. to 3 a. m., 5 to 7 a. m., 10 p. m. to 12 p. m.	69 to 79	SW	10 to 11.
23	12 p. m. to 1 a. m.	76	NE	10.
23	11 a. m. to 12 p. m.	65 to 86	SW	10 to 14.
29	5 a. m. to 12 p. m.	67 to 88	SW	10 to 19.
30	4 to 5 a. m.	68	N	10.

NE 5%
E 15%
N 25%

S
8%

SE
9%

W
13%

NW
14.5%

SW
31%

During the entire period covered by these records 51 per cent of the days when spread was possible the wind was southwest. Figure 3 shows graphically the proportion of the time when the wind blew in each direction, as given in the above tables.

In the fall of 1907 the gipsy moth was found extensively in New Hampshire, especially in the eastern part, and as a small strip along the seacoast in Maine was also infested, Weather Bureau records are here added, which have been secured from the Concord, N. H., and Portland, Me., stations.

TABLE V.—*Temperature, direction, and velocity of wind on dates after hatching of caterpillars, 1907-1911.*

CONCORD, N. H.

Date.	Hours 7 a. m. to 7 p. m.	Maximum temperature.	Direction of wind.	Velocity of wind.
1907.		° F.		<i>Miles per hour.</i>
Apr. 23	12 to 4.	65	SW., SE.	10 to 13
29	2 to 5.	66	S.	10 to 11
30	8 to 7.	74	SW., S.	12 to 20
May 10	9 to 7.	66	NW.	10 to 16
13	7 to 9.	79	SW.	11 to 16
14	12 to 5.	81	SE.	10 to 14
1908.				
Apr. 23	12 to 3, 5 to 6.	79	NW.	10 to 14
25	11 to 7.	68	SE.	10 to 13
26	9 to 5.	80	SW., W.	10 to 19
27	10 to 5.	78	SE.	11 to 14

FIG. 3.—Diagram showing the proportion of time the wind blew in each direction, when wind spread was possible, during April and May for 10 years, 1902-1911. Records from Boston office of Weather Bureau. (Original.)

TABLE V.—Temperature, direction, and velocity of wind, etc.—Continued.

CONCORD, N. H.—continued.

Date.	Hours 7 a. m. to 7 p. m.	Maximum temperature.	Direction of wind.	Velocity of wind.
		° F.		Miles per hour.
1908.				
May 11	11 to 4.....	79	NW.....	10 to 14
12	9 to 6.....	83	SW.....	10 to 16
13	9 to 6.....	68	SW.....	10 to 15
16	3 to 6.....	74	SE.....	10 to 14
17	12 to 3.....	73	SW., W.....	10 to 12
18	5 to 6.....	79	SE.....	11
19	10 to 7.....	76	SE., S.....	10 to 13
21	1 to 7.....	75	SE.....	10 to 13
24	10 to 5.....	81	NW.....	10 to 11
26	11 to 7.....	89	SW.....	10 to 15
27	8 to 1.....	85	W.....	10 to 12
30	12 to 3.....	75	E., SE.....	10 to 11
31	8 to 5.....	82	SW.....	10 to 14
1909.				
May 6	8 to 4.....	74	NW.....	10 to 13
8	4 to 6.....	69	SE.....	11 to 13
10	11 to 7.....	78	S.....	15 to 19
11	9 to 7.....	68	NW.....	10 to 25
12	8 to 6.....	68	NW.....	11 to 25
14	11 to 5.....	78	W.....	10 to 13
15	7 to 10, 2 to 5.....	71	NW.....	10 to 11
24	8 to 9, 11 to 6.....	74	NW.....	10 to 13
26	4 to 5.....	74	W.....	10
27	12 to 1.....	73	SE.....	10
30	7 to 6.....	68	NW.....	11 to 19
31	9 to 6.....	76	NW.....	11 to 18
1910.				
Apr. 6	12 to 6.....	70 to 80	SE., S.....	11 to 16
15	2 to 3.....	66	NW.....	13
19	12 to 5.....	68 to 72	SE., E.....	10 to 13
27	2 to 4.....	66 to 67	W.....	10
May 3	3 to 4.....	69	SE.....	10
7	1 to 4.....	65 to 67	W.....	10 to 11
8	2 to 5.....	65 to 73	SW.....	10 to 13
23	2 to 6.....	65 to 69	SE.....	10
24	10 to 5.....	82 to 86	SW.....	10 to 11
25	8 to 4, 6 to 7.....	66 to 77	SW., S.....	10 to 16
26	1 to 4.....	66 to 69	W.....	10 to 12
27	1 to 2.....	66	W.....	10
28	10 to 4.....	65 to 71	NW., N.....	11 to 15
29	3 to 4.....	73	SE.....	11
1911.				
Apr. 30	10 to 6.....	68 to 80	S, SW.....	11 to 16
May 1	10 to 5.....	67 to 71	SW., S.....	11 to 13
7	9 to 5.....	71 to 79	NW.....	10 to 12
8	5 to 6.....	77	S.....	13
10	8 to 1, 2 to 4.....	65 to 76	NW.....	10 to 14
11	1 to 8.....	79 to 89	SW.....	10 to 15
12	9 to 5.....	82 to 85	SW.....	10 to 14
13	9 to 5.....	65 to 71	NW.....	11 to 15
14	5 to 6.....	65	SE.....	12
15	10 to 6.....	70 to 73	SW.....	12 to 15
16	9 to 12, 1 to 3, 4 to 5.....	66 to 74	N.....	10 to 12
26	4 to 5.....	70	E.....	11
29	11 to 3, 5 to 6.....	76 to 91	W, SW, NW.....	10 to 12
31	1 to 4.....	66 to 73	SE.....	10 to 12

TABLE V.—*Temperature, direction, and velocity of wind, etc.—Continued.*

PORTLAND, ME.

Date.	Hours 7 a. m. to 7 p. m.	Maximum temperature.	Direction of wind.	Velocity of wind.
		° F.		Miles per hour.
1907.				
May 10	10 to 2.....	65 to 67	W.....	12 to 32
19	10 to 2.....	67 to 70	SE.....	10 to 14
20	1 to 3.....	65	W.....	18 to 20
1908.				
Apr. 23	10 to 5.....	67 to 75	W.....	13 to 20
26	10 to 7.....	73 to 81	SW, W.....	10 to 21
May 11	11 to 1, 3 to 5.....	66 to 77	N, NW.....	12 to 23
12	12 to 2, 4 to 5.....	67 to 69	S.....	13 to 14
13	10 to 11.....	65	N.....	12
18	3 to 4.....	67	S.....	10
19	11 to 3.....	66 to 71	S.....	11 to 18
26	11 to 7.....	67 to 75	S.....	12 to 18
27	8 to 5.....	78 to 87	W, NW.....	10 to 15
31	7 to 5.....	69 to 84	W, SW.....	13 to 20
1909.				
May 6	9 to 5.....	65 to 75	NW.....	14 to 19
11	1 to 2.....	66	S.....	11
12	11 to 5.....	65 to 67	NW.....	21 to 36
13	12 to 3.....	67 to 70	W.....	11 to 13
15	1 to 6.....	66 to 68	NW.....	12 to 14
26	9 to 4.....	66 to 70	NW, S.....	10 to 17
27	12 to 1.....	68	SE.....	10
30	2 to 6.....	65 to 67	NW.....	20 to 24
31	8 to 7.....	65 to 74	NW.....	12 to 24
1910.				
Apr. 14	1 to 3.....	65	W.....	20 to 21
27	12 to 3.....	67 to 68	SW.....	10 to 15
May 10	2 to 3.....	65	W.....	19
17	11 to 5.....	65 to 69	SE, S.....	11 to 15
20	9 to 1.....	65 to 67	NW, S.....	11 to 15
24	11 to 5.....	65 to 68	S.....	10 to 16
25	12 to 2.....	65 to 67	S.....	14 to 18
26	12 to 2.....	65 to 66	S.....	11 to 15
27	12 to 4.....	65 to 68	SE.....	10 to 15
1911.				
Apr. 27	2 to 3.....	65	SE.....	10
28	9 to 10, 2 to 9.....	65 to 74	S, SW.....	10 to 14
29	1 to 6.....	65 to 77	S.....	10 to 12
May 2	8 to 1.....	66	W.....	18 to 20
7	8 to 9, 10 to 6.....	68 to 80	W, NW.....	10 to 18
8	10 to 5.....	65 to 75	S.....	13 to 19
10	8 to 11, 1 to 3, 4 to 6.....	65 to 75	NW, N, S.....	10 to 15
12	6 to 7, 10 to 2.....	66 to 73	S, SW.....	11 to 18
13	8 to 5.....	66 to 76	W, NW.....	14 to 20
16	10 to 6.....	65 to 73	NW, W.....	12 to 16
17	12 to 1.....	67	S.....	11
18	1 to 3.....	67 to 74	SE.....	11
21	9 to 9.....	65 to 73	S.....	11 to 18
22	2 to 5.....	84 to 88	S.....	10
27	11 to 3.....	65 to 69	S.....	12 to 16
28	10 to 9.....	66 to 78	S.....	11 to 20
29	9 to 6.....	74 to 80	S.....	10 to 12
30	1 to 4.....	66 to 70	S.....	10 to 13

In order to study these tables properly the data from each State should be considered separately. Hatching takes place later in the vicinity of Portland, Me., and Concord, N. H., than in the territory surrounding Boston, because the season is later. In Massachusetts the same conditions prevail in all of the towns which are on the watersheds of the Merrimac and Connecticut Rivers. An examination of the records, however, shows that the prevailing winds

are in the same direction during the first half of June as in the month of May, so that little benefit would be derived from giving the additional data.

For convenience the record of infestation has been divided into four periods (see map 1), viz:

(1) The territory infested in 1900 at the time the work was discontinued by the State of Massachusetts.

(2) The territory found infested as a result of scouting operations after the work was resumed in the winter of 1905-6 by the State of Massachusetts.

(3) The territory found infested up to and including the winter of 1908-9.

(4) The territory infested at the present time, winter of 1911-12.

The territory infested in 1900 when the gipsy-moth work was discontinued by the State of Massachusetts was confined to 34 towns and cities surrounding Boston, covering an area of about 359 square miles. None of the area was badly infested, but a very rapid increase of the pest took place as soon as efforts to check it were abandoned. The next two years developed few signs of increase in the insect, although in several localities it was somewhat abundant in 1902. An infestation was discovered in Providence, R. I., in the summer of 1901. In the summers of 1903, 1904, and 1905 the territory in Massachusetts which had been most densely infested when the work was discontinued fairly swarmed with caterpillars, and, as little organized effort was made to check the insect, an excellent opportunity was offered for the small caterpillars to be spread by the wind. Map 1 shows the territory which was found infested by the scouting operations conducted by the State of Massachusetts, which were carried on during the summer and fall of 1905. The infestation had increased to such an extent that it covered 132 towns and extended from Portsmouth, N. H., to Buzzards Bay, including, as well, isolated colonies in Providence and Cranston, R. I., and Stonington, Conn., a total of about 2,224 square miles.

Undoubtedly the greater part of this infestation was the result of wind spread, therefore map 1 indicates the number of days the wind blew in each direction during the period when caterpillars were in the first stage, and when the temperature and wind velocity were favorable to their dispersion. Eliminating the west wind from consideration, which would take the larvæ out to sea, it will be noted that, except for seven days when it was from the east and north, the direction of the wind would account in a general way for the infested region as shown by the map. It is probable that more area would have been found infested in southern New Hampshire in 1905 if it had been possible to scout the towns nearest Massachusetts, but there were no funds available for this purpose.

During the period from 1906 to 1909 a large extent of scouting was done by the State of Massachusetts in the territory outside of the area known to be infested, and, as a result, 44 new towns and cities were found infested. Isolated colonies were found at Greenfield, at Palmer, at Springfield, and at Warren during the scouting operations, but all of them have since been exterminated. In New Hampshire scouting work was carried on under the direction of Mr. D. M. Rogers, special agent of the Bureau of Entomology. The infested area was found to have greatly increased. Scouting was also carried on in Maine and Rhode Island and showed that the infested area was increasing, and one isolated colony was found in Togus, Me. At the close of this period of scouting the entire area of infestation covered nearly 7,300 square miles. The greater part of the spread had been toward the northeast and northwest, and it is interesting to note that the prevailing winds blew in these directions, especially from the southwest. (See map 1.)

During the period from 1909 to 1912 the infested territory has continued to increase. Nearly all the scouting work has been done by agents of the Bureau of Entomology, although a small force has been employed by the States of Maine, Massachusetts, and Connecticut. The infested territory has continued to increase along the line of the prevailing winds, as is shown on map 1 and by its wind diagram. In the fall of 1909 an isolated colony was found at Wallingford, Conn., but careful scouting for miles in all directions has failed to locate other infestations in that part of the State. It is probable that egg clusters were brought to Wallingford on market boxes or in packing material. The thorough treatment which has been given under the direction of the State entomologist, Dr. W. E. Britton, and his assistant has reduced the colony to a point approaching extermination. The same is true of the colony at Stonington, Conn.

In the summer of 1911 the gipsy moth was discovered on an estate in the town of Lenox in the western part of Massachusetts, and scouting work has resulted in locating it in Stockbridge and Great Barrington. It is probable that in Lenox and Stockbridge the infestation resulted from the receipt of a carload of nursery stock (Pls. XIV, XV, XVI) which was shipped by the Boston Park Department about 1909 to the estate where the infestation was found. The origin of the Great Barrington infestation is obscure, but further scouting of the town may uncover conditions which will explain the reason. The colony at Togus, Me., has been exterminated, no specimens having been found since 1908.

As a result of the scouting operations during the past winter it is shown that 10,900 square miles are now infested with the gipsy moth. The territory which is now badly infested is well outside



ROW OF LARGE MAPLE NURSERY STOCK INFESTED BY THE GIPSY MOTH.

A gipsy-moth egg cluster is on the tree in the center of the picture, as indicated by arrow, just above the black spot. (Original.)



GIPSY-MOTH EGG CLUSTER ON SMALL NORWAY SPRUCE TREE IN NURSERY ROW.

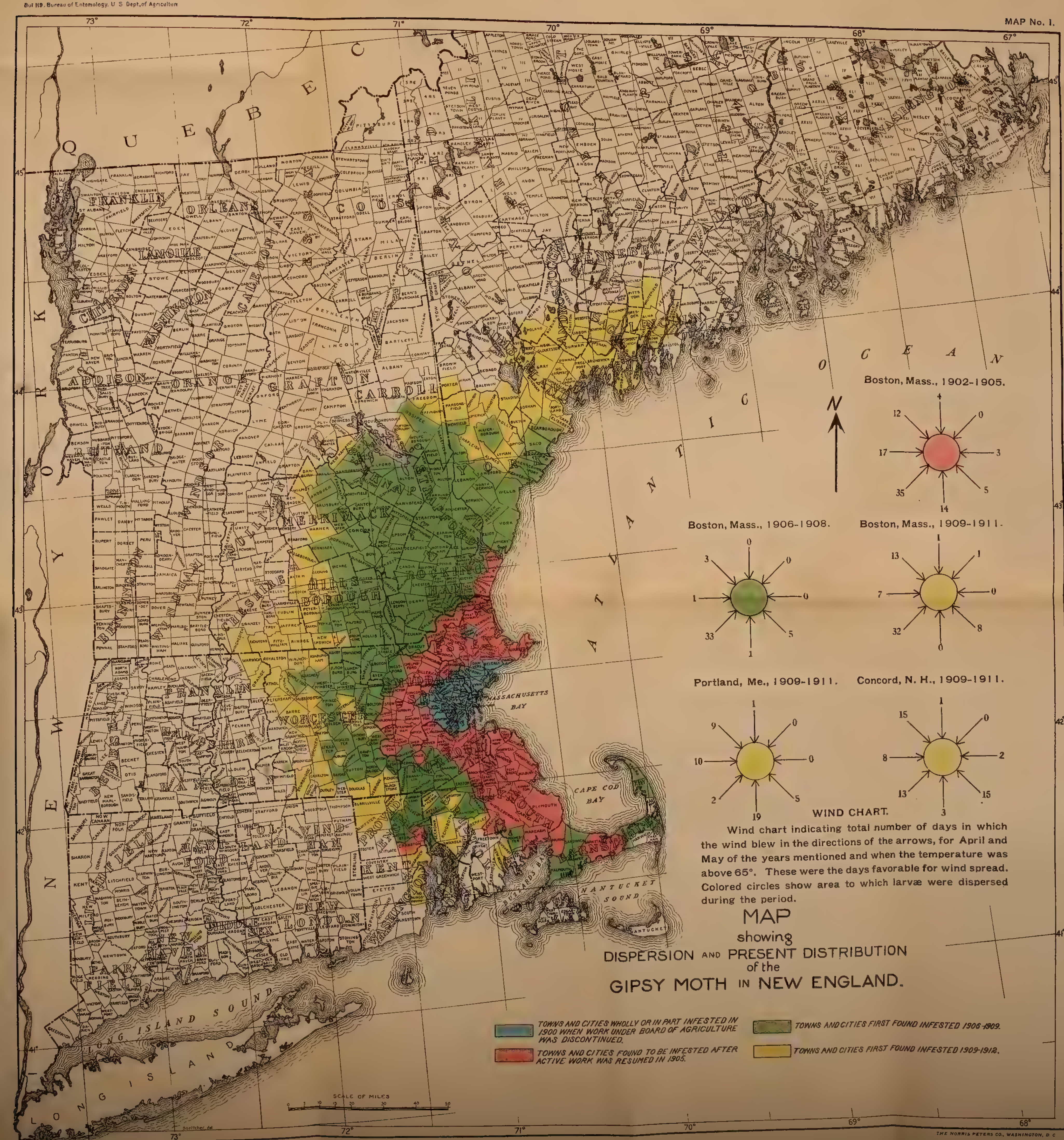
The upper branches of the tree have been tied up so as to expose the egg cluster. (Original.)



WEeping MULBERRY SHOWING BIRD'S NEST AND NEAR BY TWO GIPSY-MOTH
EGG CLUSTERS.

Their location is indicated by the arrows. The egg cluster in the background is nearly
obscured by the shadow. (Original.)





of that which was infested in 1905. This being the case, the opportunity for spread has greatly increased, and as the insect gradually becomes established on the western slope of the high lands in the central part of the State, the opportunity for serious damage in the Connecticut valley is rapidly increasing.

In connection with the weather record given for this period it is interesting to note the corresponding data from the Weather Bureau stations at Portland, Me., and at Concord, N. H., as these data have a bearing upon the spread in the northern part of the territory.

GENERAL SUMMARY.

The map and wind direction records give a fairly good idea of the dispersion of the gipsy moth. The spread has been along the lines of the prevailing winds to so great an extent that the evidence is conclusive that natural spread is accomplished chiefly in this way. All the records bear out this conclusion. It should be noted in the Concord records that the southeast winds were the ones which were most likely to carry the larvæ into new territory, while in Portland the south and west winds which predominated would do the same thing in that section. It should be remembered that neither Concord, N. H., nor Portland, Me., has been badly infested and that the spread must come from bad colonies nearer the center of infestation.

The general "seeding down" of slightly infested territory by larvæ spread by the wind is shown in some detail in the following pages.

GENERAL CONCLUSIONS.

It is impossible to give a detailed explanation of the cause of every infestation. The weather records give strong evidence that the wind is responsible in a large degree for the spread of the gipsy moth, but the spread can be brought about only under the favorable conditions which have already been explained. The present apparatus for recording wind movements is somewhat imperfect, and as the wind is usually very variable it is probable that a greater local spread results than can be explained from wind records. Other things being equal, wind spread will start the most vigorous colonies nearest the bad centers of infestation,¹ for the farther the caterpillars are carried the more chance there is for them to become widely separated, so

¹ On May 19, 1912, Mr. C. W. Stockwell found that large numbers of first-stage gipsy-moth larvæ that hatched a few days before were being blown from an isolated block of birches into a pasture by a strong southwest wind. At a point 125 feet from this block he found from 21 to 27 larvæ per square foot; they were crawling about on the grass seeking food. On the posts of a wire fence, 185 feet from the birches, over 500 larvæ were found on each post, and smaller numbers of larvæ were found at a greater distance away. This substantiates the experiments previously made, and shows what happens in nature under favorable conditions. It also proves that the heaviest infestations brought about by wind spread will be nearest the colony from which the larvæ were spread.

that infertile egg clusters will result in case any are deposited. Cases are on record where a male gipsy moth has been attracted half a mile by a female. This factor probably assists the species in becoming established at distant points.

RELATION OF SCOUTING RECORDS TO WIND DISPERSION.

The records which have accumulated showing the number of egg clusters found and treated by scouts in the various towns, as well as the reports of the work done by local superintendents, have been examined for the purpose of determining whether information could be secured that would have any bearing on the dispersion of the insect. As a result of the examinations it appears impossible to give data covering the entire territory, since the records are incomplete in many cases and they have been kept in various ways so as to make a comparison of little value. The plan has been to select several towns and cities (see fig. 4) where complete records were obtained. The geographical locations of these are typical, so that the results will serve to illustrate the relation of wind to infestation as found by scouts. It should be remembered that no woodland area is included in the records cited, for only roadsides, orchards, and the grounds about residences were examined.

In order to check this data a complete scout has been made of several towns by employees of the Bureau of Entomology, United States Department of Agriculture, working under the direction of Mr. Rogers. This included a careful examination of the wooded areas as well as the roadside trees.

RECORDS OF DISPERSION OF THE GIPSY MOTH SECURED FROM REPORTS OF SCOUTING IN SEVERAL SELECTED CITIES.

For the purpose of making a comparison showing the rapidity of infestation in different localities (fig. 4) the cities of Brockton and Worcester, Mass., and Nashua, Manchester, Concord, and Portsmouth, N. H., are given in Table VI.

TABLE VI.—*Record of egg clusters of the gipsy moth found in certain cities of New England during the years 1905-11.*

Cities.	1905-6	1906-7	1907-8	1908-9	1909-10	1910-11
Massachusetts:						
Brockton.....	24	127	283	3,101	1,575	5,600
Worcester.....	0	0	44	32	31	275
New Hampshire:						
Nashua.....	0	9	176	910	16,759	¹ 17,607
Manchester.....	0	2	53	456	(²)	¹ 16,598
Concord.....	0	0	(³)	93	1,855	4,419
Portsmouth.....	2	175	802	9,417	72,294	¹ 72,000

¹ Estimated.

² No record.

³ 1 pupa.

The records for the winter of 1911-12 are not given, as it was impossible to secure the information from some of the cities mentioned. The data concerning the infestation in cities and towns in Massachusetts have been kindly furnished by State Forester F. W. Rane and his assistants, while similar data from the other States have been supplied by Mr. Rogers. It will be noted that the city of Brockton was found infested in 1905-6 and that the same is true of Portsmouth, N. H. An excellent opportunity is offered for comparing the number of egg clusters found in these two cities from year to year. It will be observed that at the end of the fifth year 1,575 egg clusters were found in Brockton, while over 72,000 were treated in Portsmouth, N. H. This indicates very strongly that new infestations were continually being brought about through the spread of caterpillars by the wind.

Somewhat the same conditions will be noted on comparing the record of infestation at Worcester with that of Nashua, Manchester, and Concord. The increase in Worcester for the period shown in the table is slightly less than that in Brockton, which shows that the wind was more favorable for spread in the direction of the latter city.

It should be noted that all the newly infested points were treated each year, and in many cases colonies were exterminated, but as a rule a larger number of new infestations were found in different parts of the cities the next year, and the total of egg clusters usually showed an increase.

In connection with these data it is interesting to consider the record of infestation in the State of Rhode Island. The gipsy moth was first found in the city of Providence in 1901, and some work was done to control the insect during the five succeeding years.

In 1906-7 a careful examination was made by agents of the Bureau of Entomology in cooperation with the State of Rhode Island, and several towns surrounding that city were found infested. In all, 79,000 egg clusters were found and treated. In 1907-8, 7,500 egg clusters were found, and the following winter only 1,164 were discovered. During the next two winters there was a slight increase in the number of egg clusters found, as several newly infested places were discovered. No work was done in the summer of 1911, because the State failed to provide the necessary funds. During the winter of 1911-12 an examination made by the agents of the Bureau of Entomology showed that the insect had increased rapidly, 37,293 egg clusters having been found and five new towns having been infested.

The territory infested includes both city and country, and the figures show how rapidly reinfestation takes place after suppression work is stopped. The data also indicate that the rate of increase is

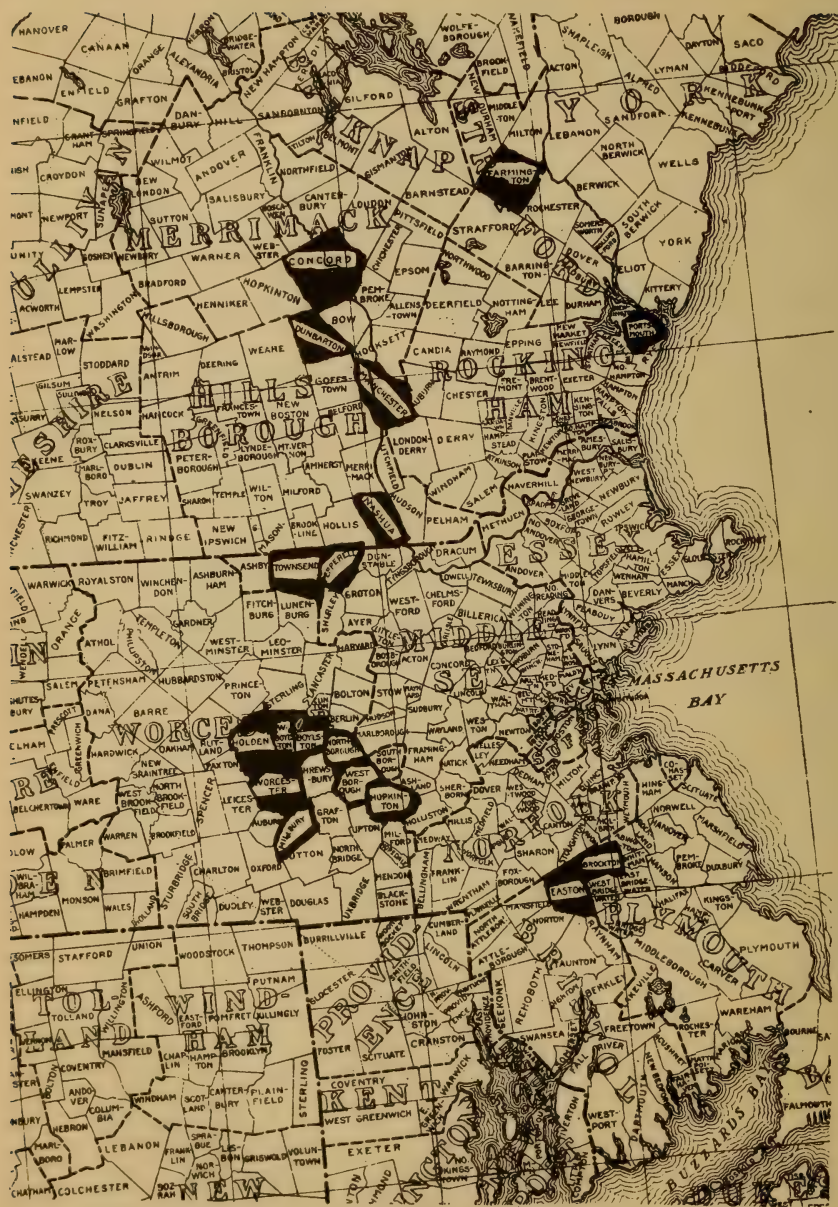


FIG. 4.—Map showing location of towns and cities in New Hampshire and Massachusetts where scouting records have been consulted to compare the relation of infestation to wind spread. (Original.)

much less in this State than in the cities in New Hampshire noted in Table VI, which is due largely to the fact that the region is out of the line of natural spread and reinfestation by the wind.

The common trees growing in Rhode Island are as much if not more favored for food than those in the cities mentioned.

RECORDS OF DISPERSION SECURED FROM SEVERAL SELECTED TOWNS.

In order to check the data just given the records of several outlying towns (fig. 4) in different sections of the infested district are supplied in the accompanying table.

TABLE VII.—*Record of egg clusters of the gipsy moth found in certain towns of New England during the years 1906–1912.*

Towns.	1906-7	1907-8	1908-9	1909-10	1910-11	1911-12
Massachusetts:						
Easton.....	3	8	47	141	503	1,789
Hopkinton.....	267	1,417	4,283	2,124	3,448	(¹)
Westboro.....	(²)	.....	.....	.....	846	1,897
Northboro.....	.....	.....	(³)	14	341	1,421
Boylston.....	.....	.....	.....	1	140	378
West Boylston.....	.....	.....	.....	7	156	455
Holden.....	.....	.....	.....	9	45	33
Millbury.....	.....	(³)	.....	3	4	.....
Pepperell.....	.....	32	12	.....	.....	.....
Pepperell.....	.....	87	765	(¹)	(¹)	(¹)
Townsend.....	4	1	4	524	3,613	12,862
New Hampshire:						
Dunbarton.....	.....	.....	25	308	2,825	42,147
Farmington.....	.....	.....	125	1,170	3,260	(¹)

¹ No record.

² 7 collected.

³ 1 pupa.

⁴ Partial record.

The record of infestation—that is, the record showing the number of egg clusters found while scouting various towns from year to year—is interesting, as it gives in a way the rate of increase, although it should be understood that all egg clusters which are found are treated with creosote, and in most cases the infested areas are attended to during the caterpillar season and all the larvæ found are destroyed. Only roadsides, orchards, and private estates are examined and treated. In most cases the towns have large woodland areas which it is impossible to examine owing to the expense involved. The record of the infestation is given for several towns, which shows that dispersion must be due to causes other than vehicles.

The data for the town of Easton were furnished by Mr. L. W. Hodgkins, an agent of the State forester of Massachusetts, who had charge of a section of southeastern Massachusetts for several years. The town has been examined and the infestations treated each year, the number of egg clusters showing a slow but continuous increase since 1906, the year when the first infestation was found. During

that year single egg clusters were discovered in each of three localities. In the fall of 1911, 1,789 were found in 326 localities.

The gipsy moth was first found in Hopkinton, Mass., in 1905, and the writer is indebted to Mr. G. A. Sands, of the Massachusetts State forester's office, for data concerning this town. During the winter of 1906-7, 267 egg clusters were secured from 39 different localities. In 1907-8, 1,417 egg clusters were secured in 30 localities. In 1908-9, 4,283 egg clusters were found in 90 colonies. In 1909-10, 2,124 egg clusters were treated in 70 localities. In 1910-11, 3,448 egg clusters were found in 80 localities. In some of these colonies no egg clusters were located during the year following the first examination, as the trees were burlaped, examined during the summer, and the colonies exterminated. In other places small numbers of egg clusters were found from year to year, but each year it was possible to obtain them in regions where they had not been known previously.

The original colony in Hopkinton was southeast of the village, near the roadside. The following year infested places were found near the center of the town, and a few were located near the borders of the adjoining towns. The next year egg clusters were found well scattered throughout the town, especially in the residential section, and this condition prevails at the present time. Owing to the location of the various infestations, it is highly improbable that the insects could have spread by artificial means. For the past two years very little work has been done in this town to suppress the moth.

The data for several towns following were supplied by Mr. H. B. Ramsey, an agent of the Massachusetts State forester, and the writer is indebted to him for this and other valuable information furnished.

The condition in Westboro, a town northwest of Hopkinton, was not so bad in 1906-7, there having been found at that time only seven colonies. The number of colonies, however, steadily increased. In 1910-11, 116 were located, containing 846 egg clusters, while in 1911-12, 1,897 egg clusters were found in 214 localities.

Directly northwest of Westboro is the town of Northboro, in which no egg clusters were found until the winter of 1909-10, although three pupal cases were secured during the previous year. Northboro is west of Marlboro, which was found infested in 1905, and if dispersion of the species was equal in all directions, should have become infested rapidly. During the winter of 1909-10 five colonies were found, 14 egg clusters being treated in them. They were located in the southeastern and north-central parts of the town. The following year 95 colonies were secured, and in these 341 egg clusters were treated. In 1911-12, 1,421 egg clusters were found on 180

estates. The colonies were scattered through practically every section of the town, a few more being found near the center than in the outskirts.

Northwest of the town of Northboro is the town of Boylston (fig. 5). One egg cluster was found here in the winter of 1909-10, and during the following year 140 were found in 41 different localities. In 1911-12 141 egg clusters were found in 41 localities scattered over the town.

West Boylston, a town directly west of Boylston, was scouted by the inspectors employed by the State of Massachusetts in the winters of 1907-8 and 1908-9, but no egg clusters were found. During the winter of 1909-10 seven were secured on five estates, and during the following winter 30 estates were found infested with 156 egg clusters. During the winter of 1911-12 378 egg clusters were found on 75 estates.

The town of Holden, which is directly west of West Boylston, shows an increase quite similar to those already mentioned. A single female pupa was found during the winter of 1907-8, but the following year nothing was discovered when the scout was made. In the winter of 1909-10 nine estates were found in-

festated, each with a single egg cluster, while in 1910-11 10 estates were infested with 45 egg clusters. In 1911-12 a large increase was found, 455 being discovered on 67 estates.

The city of Worcester is located south of Holden, and was first found infested in the summer of 1907, when Mr. D. M. Rogers found a few caterpillars on an estate on Hope Avenue. During the winter of 1907-8 the city was scouted and 44 egg clusters were found on seven estates. These were well scattered over the city, and, owing



FIG. 5.—Map of town of Boylston, Mass., showing increase in gipsy-moth-infested localities, 1909-10 and 1910-11. (Original.)

- Single infestation found in winter 1909-10.
- X Infestations found in winter of 1910-11.

to the large traffic by automobiles and trolley cars from the badly infested district in eastern Massachusetts, it is very probable that the infestation may have been brought about by the carriage of caterpillars in this way. These colonies received careful attention during the summer. In the winter of 1908-9 16 estates were found infested with a total of 32 egg clusters. Fourteen of these estates were near Worcester Academy; the other two were in the eastern section of the city. Only a few egg clusters were found on the estates which were infested the previous year. In 1909-10 10 infested estates were found, with a total of 31 egg clusters, well scattered through the city. Only one of these was on property which was found infested the previous year. In 1910-11 275 egg clusters were found on 145 estates, every section of the city being included in the infested area. In 1911-12 3,570 egg clusters were found on 424 estates. It seems probable that during the period from 1907 to 1910 the greater part of the infestation may have come from traffic, but one can not escape the conviction that during the summers of 1910 and 1911, as the infestation to the south and southeast became more pronounced, a large number of the colonies resulted from wind spread. It should be remembered that the chances for spread by traffic in a large city are far greater than in the country districts. The data concerning Worcester are given because the city resembles many of the towns mentioned, inasmuch as it is very hilly, so that spread by air currents is very probable.

The town of Millbury, which adjoins Worcester on the south, has a record which is of considerable interest, inasmuch as the infestation has been decreasing from year to year. In the winter of 1907-8 32 egg clusters were found on five estates. These were all located in the central part of the town not far from the railroad. The following year no new egg clusters were found in these localities, but two other infestations, containing 12 egg clusters, were located, one near an infestation of the previous year, close by the railroad, and the other a considerable distance west of any previous infestation. In the winter of 1909-10 three new infestations were found, each containing an egg cluster, but no clusters were found in the old infested area. In the winter of 1910-11 nothing was found in the area infested the previous year, but three separate infestations, containing four egg clusters, were found in the Bond Hill section of the town east of the railroad. In 1911-12 33 egg clusters were found in six localities. The conditions in this town are quite different from those in any town previously mentioned. So far as is known, no bad infestations occurred in the region directly south, so that there would be far less opportunity for spread by the wind than would be the case in the other towns mentioned. It seems probable

that early infestations may have been brought about by automobile traffic, but this, of course, can not be proved.

The data from the two towns of Pepperell and Townsend, which are nearly due north from the towns already mentioned and are bounded on the north by the New Hampshire State line, have been furnished by the local moth superintendents, Mr. J. Tune and Mr. George E. King, and are given, as they show a contrast in the increase in infestation over most of the towns already mentioned.

The town of Pepperell was found infested the same year as were the town of Westboro and the city of Worcester. It lies about 40 miles north of Westboro, and instead of immediately adjoining towns that were infested with the gipsy moth in 1905, as was the case in the town of Westboro, it is located more than 12 miles from the nearest town that was found infested at that time. In the winter of 1906-7 4 egg clusters were found near the center of the town by State inspectors. These were properly treated, and during the following winter 87 egg clusters were discovered and creosoted. In the winter of 1908-9 756 egg clusters were found, and since that time the insect has become so abundant that no effort has been made by the local moth superintendent to keep a record of those that were found and treated.

The town of Townsend adjoins Pepperell on the west, and was first found infested one year later than the towns of Pepperell and Westboro, and the same year as the towns of Holden and Millbury, a record of which has already been given. The infestation in Townsend is interesting, inasmuch as the record has been carefully kept by the local superintendent, Mr. George E. King. In the winter of 1907-8 1 egg cluster was found in the western part of the town. It was treated with creosote, the trees were burlaped, and later 5 caterpillars were found and destroyed. In the winter of 1908-9 1 egg cluster was found in the eastern part of the town and treated in the same way, and 3 egg clusters were found near the center of the town, and as a result of burlaping 15 caterpillars were killed during the summer. The following winter 65 different colonies were found scattered throughout the town. Five hundred and twenty-four egg clusters were treated and 10,500 caterpillars were destroyed during the summer. During the winter of 1910-11, 245 colonies were found scattered throughout the town, a large number being in orchards along roadways. In these colonies 3,613 egg clusters were destroyed, and later in the season about 20,000 caterpillars were killed. On February 27, 1912, Mr. King informed me that 12,862 egg clusters had been found in 257 localities, and that the work for the winter of 1911-12 was not nearly completed. The increase in the number of colonies found and the number of egg clusters and caterpillars destroyed is in marked contrast to the

record of infestation of Westboro, which was much nearer the badly infested territory, and, other things being equal, should have become badly infested sooner than Townsend, where the first infestation was located a year later.

The scouting of Dunbarton and Farmington, N. H., has been carried on by scouts working under the direction of Mr. D. M. Rogers, and Table VII shows that the infestation has been greater than that in the towns given in central Massachusetts, and about the same as that found in Townsend.

It will be observed that in Westboro seven colonies, containing 377 egg clusters, were found in 1906-7, which indicates that the moth was present the previous year, and probably would have been found if there had been sufficient time to make a thorough inspection. In the winter of 1911-12 214 colonies were found and 1,897 egg clusters were treated. When this is compared with the record given for Townsend, which started from one egg cluster in the winter of 1907-8, one can not escape the conviction, inasmuch as most of the infestations recorded in the winter of 1911-12 were in localities which had previously not been known to be infested, that the rapid infestation of this territory was due to the dispersion of young caterpillars by the wind.

PLANS FOR SCOUTING WOODLAND AREAS.

Many data have been given showing that the dispersion of the gipsy moth is largely due to small caterpillars carried by the wind, but it seemed desirable to determine whether the woodland areas in the towns where only a few colonies existed were becoming infested by this insect. The matter was thoroughly discussed by Messrs. Fiske, Rogers, and the writer, and as a result plans were made to scout large areas in several of the outlying towns. The plans were approved by Dr. L. O. Howard. It was arranged that the scouting work should be carried on under the direction of Mr. Rogers, and it was begun in October, 1911. Owing to the severe winter and heavy snowfall in the infested territory it was impossible to finish all the towns until late in the spring of 1912. The work was carried through, however, and a statement of the results follows.

The original plan contemplated the examination of every tree in the whole or a part of the towns of Lisbon and Yarmouth, Me., Milton, Tilton, and Bennington, N. H., and Gardner, Grafton, and Wareham, Mass. (See fig. 6.) It will be noted that these towns are located in the sparsely infested area (map 1), and it was expected that some interesting data on wind dispersion would be secured. Work in Bennington, N. H., was carried on under the direction of General Foreman I. L. Bailey; that in Maine and in Tilton and Milton, N. H., and Grafton, Mass., was directed by General Foreman H. L. McIn-

tyre. The work in Wareham was carried on under the direction of C. E. Totman and C. B. Whitaker, while that in Gardner was directed by Henry N. Bean. It should be noted at the outset that the character of the forest has a great influence on the liability to infestation, because if the caterpillars are carried by the wind and dropped upon trees upon which they can not feed, no infestation will result. Therefore it is to be expected that in sections where coniferous trees predominate the chances of new infestation will diminish, even although the region is in line with the prevailing wind during the time the caterpillars are likely to be carried by it.

RECORD OF SCOUTING IN LISBON, ME.

On October 23, 1911, the work in Lisbon, Me., was begun by Mr. C. E. Totman and a crew of experienced scouts, and the territory north of the Androscoggin River and east of the Maine Central Railroad was examined. This covered about $16\frac{1}{2}$ square miles, about 40 per cent of which was woodland. The land in this town is rolling, and a considerable portion is cleared and cultivated.

The percentages of the various kinds of trees in the regions scouted were estimated by Mr. Totman, as follows:

	Per cent.		Per cent.
Conifers -----	40	Elm -----	2
Oak -----	3	Birch -----	7
Maple -----	17	Beech -----	18
Ash -----	7	Miscellaneous -----	6

It will be noted that about half of the food plants (conifers and ash) are unsuitable for food for first-stage gipsy-moth caterpillars, so that of the $16\frac{1}{2}$ square miles covered only $3\frac{1}{4}$ square miles of the area supported trees upon which the gipsy moth would survive if it were introduced. The oak, which is the favorite food, comprised only 3 per cent of the tree growth. Roadsides in this town were scouted in the winter of 1910-11, and nine infestations were found in the territory under consideration, a single egg cluster being obtained in each locality. These were treated at the time. The results of the present scouting showed that no infestations were present where eggs were found last year, but 18 new infestations were located. Only one of these was in woodland, and in this case seven egg clusters were found on the bank of the Sabattus River. Thirteen egg clusters were found on trees along the roadside, east of the town, and two were located on another road near by. Each of the remaining infestations at different points along the highway contained a single egg cluster or a pupal case. It is improbable that the infestations along these roads resulted from previous infestations, although a few egg clusters may have been overlooked. Lisbon is located at least 70 miles from badly infested territory, so that bad woodland infestations were hardly to be expected.

RECORD OF SCOUTING IN YARMOUTH, ME.

Scouting operations were commenced in Yarmouth, Me., on October 23, 1911, by a crew of experienced scouts under the control of Mr. A. M. G. Soule. All the territory east of the Grand Trunk Railroad and south of the Maine Central Railroad, about 7 square miles, was examined. This section of the town of Yarmouth consists largely of cleared land and pastures. The wooded areas are in relatively small blocks, less than 3 square miles of the area being in woodland. The tree growth was rated by Mr. Soule as follows:

	Per cent.		Per cent.
Conifers	30	Birch	11
Oak	49	Miscellaneous	9
Maple	1		

It will be noted that nearly one-half of the trees in the area are oak; that conifers were 10 per cent less than in the district scouted in Lisbon; and that the area, although smaller, was more suited to rapid infestation, owing to the character of the tree growth.

During the winter of 1910-11 15 infestations were found in the entire town, 7 of them being in the area under consideration. All of these places were along the highways or in orchards. Five of the seven each had a single egg cluster, one had two clusters, and in the other a pupal case was secured. No egg clusters were found in these places this year, but a total of 27 infestations, containing 56 egg clusters, was discovered. Five of the colonies were in woodland, and in one of them 17 new clusters and 1 old one were found.

Yarmouth is located nearer the badly infested area than Lisbon, and more woodland infestations should be expected than in the case of the latter town.

RECORD OF SCOUTING IN MILTON, N. H.

On October 25, 1911, a crew of experienced scouts under the direction of William Sarsfield commenced the examination of the trees in Milton east of the Boston & Maine Railroad. This territory is hilly and the towns south and southwest of it are generally very badly infested. The area examined covered about 18 square miles, 13 of which are wooded. The forest growth was as follows, according to estimates furnished by Mr. Sarsfield:

	Per cent.		Per cent.
Conifers	29	Elm	4
Oak	13	Beech	29
Maple	16	Miscellaneous	7
Ash	2		

In the winter of 1910-11 the orchards in this area were scouted and 21 infestations were found, practically all of which had a single egg cluster. In the whole town, the greater area of which is on the west side of the railroad, 159 egg clusters were found in 55 localities.

In 1911-12 14 woodland infestations of 59 egg clusters and 22 orchard and roadside infestations of 202 clusters were found east of the railroad. The woodland infestations were in the territory between the Milton railroad station and the south end of the town. In the part of the town west of the railroad only the roadsides and orchards were examined, and 6,602 egg clusters were found in 57 localities.

The results of scouting in this town show that the infestation is increasing rapidly in both woodland and orchards. The figures for the two years are significant, for in the western part of the town the infested localities in one year more than doubled, and the number of egg clusters was more than 40 times greater than the previous year.

RECORD OF SCOUTING IN TILTON, N. H.

Examination of Tilton, N. H., was begun November 1, 1911, by Mr. C. E. Boardman and a crew of experienced scouts. The area of the town is about 10 square miles, less than one-third of this being wooded. According to Mr. Boardman's estimates the tree growth is as follows:

	Per cent.		Per cent.
Conifers-----	30	Elm-----	2
Oak-----	13	Birch-----	12
Maple-----	35	Miscellaneous-----	6
Ash-----	2		

In 1910-11 the roadsides and orchards in the town were scouted, and four infestations containing 889 clusters were found. In one of these over 800 clusters were treated, and during the following summer over 4,800 caterpillars and pupæ were destroyed under burlap. As a result of the present scout only 11 egg clusters were found in three orchard and two woodland infestations, one of the latter being near the bad infestation of the previous year. This shows that good work was done in controlling and reducing the infestations found and that reinfestation by natural or artificial spread in this area has been slow.

Tilton is located 20 miles north of Concord, N. H., and most of the badly infested area lies to the southeast; some, however, is near Concord and extends to the south.

RECORD OF SCOUTING IN BENNINGTON, N. H.

Bennington is located about 25 miles west of Manchester, N. H. The land in the eastern part of the town forms a part of the watershed of the Merrimac and Contocook Rivers. Almost one-half of the area is wooded. An examination of this town was begun

November 1, 1911, by scouts in charge of Mr. W. T. Kelly. The tree growth was rated by him as follows:

	Per cent.		Per cent.
Conifers-----	25	Ash-----	2
Oak-----	21	Birch-----	27
Maple-----	25	Miscellaneous-----	10

In all about 5 square miles of woodland were scouted, and as the town is very hilly it was hoped that evidence of wind dispersion might be found on the high land.

In the winter of 1910-11 the roadsides and orchards were examined, and eight egg clusters were found in two localities. As a result of the present scouting no infestations were discovered in these places, but two new orchard colonies, one containing eight and the other three egg clusters, were found. No egg clusters were found in the woodland.

Practically all of the badly infested territory lies to the east and south.

RECORD OF SCOUTING IN GARDNER, MASS.

On April 26, 1912, scouting in Gardner, Mass., was begun by Mr. F. W. Foster and a crew of experienced scouts working under the direction of Mr. H. N. Bean. A part of the woodland west of the Boston & Maine Railroad and north of the Fitchburg Railroad, covering almost 2,368 acres, was examined. Owing to the predominance of coniferous and sprout growth two other areas were selected north and east of the town, where deciduous trees were abundant.

Gardner is on the ridge of land which forms the watershed of the Connecticut and Merrimac Rivers and their tributaries, and on account of its elevation, about 1,300 feet above sea level, it was thought that evidence of wind spread of the larvæ might be found. The examination showed, however, that the forest growth was not favorable for infestation. The season is considerably later in this locality than in the lower land near Boston.

Gardner is a large chair-manufacturing center, and most of the hardwood has been cut off, presumably to be used for that purpose.

The kinds of tree growth examined were rated by Mr. Foster as follows:

	Per cent.		Per cent.
Conifers-----	67	Beech-----	3
Oak-----	2	Birch-----	10
Maple-----	13	Miscellaneous-----	5

Many orchards in this city are slightly infested, but no large colonies have ever been found. The scouting work resulted in the discovery of only one infestation in woodland which was located far enough from orchard infestations so that the larvæ might have been

carried a considerable distance by the wind. The infestation mentioned was in a small block of woodland, mostly deciduous growth, which borders Crystal Lake, and is west of Woodland Avenue, and in this place four new egg clusters were found. Another infestation of a single egg cluster was on a maple tree 500 feet from the highway, but there were two infested orchards within 1,000 feet, and it is probable that the spread came from these orchards. The caterpillars may have been carried by the wind or on men or animals. A third infestation was found near the Winchendon line, but egg clusters had been previously discovered on several old apple trees in a pasture near the woodland.

Any of these colonies may have been brought about by wind spread, but the evidence is not strong. The unfavorable character of the trees would prevent, to a large degree, the establishment of the insect in woodland in this town.

RECORD OF SCOUTING IN GRAFTON, MASS.

On March 11, 1912 an examination of Grafton, Mass., was begun by scouts working under the direction of Mr. H. L. McIntyre. All the territory east of the Grafton & Upton Railway was examined, and a part of the woodland near Farnumsville was also scouted. The town is generally infested with the gipsy moth, and it is possible to find egg clusters in nearly every orchard. The area examined covered about 5 square miles of woodland. No orchards or estates were scouted. The different kinds of trees in the woodland were estimated as follows:

	Per cent.		Per cent.
Conifers-----	6	Chestnut-----	18
Oak-----	21	Ash-----	1
Maple-----	23	Birch and beech-----	14
Elm-----	1	Miscellaneous-----	16

As a result of the scouting the following infestations were located:

One old egg cluster on a birch tree in woodland near North Grafton, two colonies on the land of the State insane hospital, one of 18 egg clusters near the barns, and the other of 25 egg clusters on a large oak tree on the edge of the woodland in the rear of one of the buildings. As there is quite a general infestation of the fruit trees on these grounds it is probable that these colonies were established by caterpillars carried on men or farm animals to the places where the egg clusters were found. An infestation of two clusters was located near the Westboro line in oak growth. Five infestations were found in two blocks of woodland on Esterbrook Avenue. In one block, where three colonies were found, four egg masses were discovered, three new and one old, while in the other

block two colonies on low land totalled 149 new and 27 old egg masses. Most of the trees in these areas were pine, maple, and birch, with a few oaks and chestnuts. On the whole, these colonies were not very favorably situated for rapid increase of the species. One old egg cluster was found in woodland south of Grafton Center, and a colony of 20 nests was found on two apple trees in a block of woodland near Farnumsville.

The discovery of old egg clusters is noted above, because it is probable that new clusters were present in obscure places on the tree or on the ground and were not observed by the scouts. During a part of the time several inches of snow covered the ground.

In all the places mentioned it is probable that five infestations may have been brought about by wind spread, although this can not be stated with certainty owing to the state of infestation of the orchards in the town. Grafton was first found infested in the winter of 1908-9. It is located only 7 miles west of Hopkinton, where the gipsy moth was found in 1905.

RECORD OF SCOUTING IN WAREHAM, MASS.

Scouting in Wareham was begun March 28, 1912. As it was impossible to secure definite results by examining a section of the town on account of the prevalence of coniferous growth, several areas were selected, covering in all about 925 acres, and a scout of this territory was made.

This area was used because hardwood growth predominated and, on the average, about 75 per cent of it was oak.

As a result of the examination 112 egg clusters were discovered in eight localities.

Two small infestations were found near the road leading from the Tremont station; another was in woodland near West Wareham, 50 egg clusters having been found. The white pine in this area had been cut, so that only deciduous trees remained. A short distance away were located trees that had been infested for two or three years, and this may explain the source of this colony.

A block of dead oak growth on high land near West Wareham contained two colonies, one of 50 and the other of 2 egg clusters. Apparently these were caused by wind spread, as there were no infested places near by, so far as could be ascertained.

Three other colonies, of a single egg cluster each, were located. One was on the back road between Wareham and West Wareham, and the other two were southeast of the Wareham railroad station. Two of these may have been brought about by wind spread, but the third was near the site of a colony which had been treated for several years.

The result in Wareham indicates that there may have been some dispersion by the wind, but only a few of the colonies can be accounted for in that way.

RESULTS OF SCOUTING WOODLAND AREA.

On the whole, the number of woodland infestations found is not so large as might be expected. Those at Milton, N. H., and Yarmouth, Me., are the most striking, probably furnishing the most definite results of any of the towns under consideration. Owing to the long distance from Lisbon, Me., to the nearest badly infested area, which is about 70 miles, and to the large quantity of unfavorable food for the caterpillars, it is not surprising that little evidence was secured to show that the infestations were caused by the wind. The other infestations in the town, however, indicate that there may have been a short-distance spread in this way. In Yarmouth, Me., the proportion of coniferous growth was practically the same as that in Milton, N. H., but the wooded area examined was only about one-fourth of that scouted in the latter town. Oak trees, however, predominate in the woodland in Yarmouth; hence it is not surprising that a larger number of colonies were found in that town than in Lisbon. More woodland colonies were found in Milton than in any other town, and this is what would naturally be expected, as it is near badly infested towns and is located so that the prevailing wind would convey large numbers of the small caterpillars. The woodland examined contained only about 13 per cent of oak. If this species had been as abundant in Milton as it was in Yarmouth far more serious infestations would probably have resulted.

Scouting in Tilton indicates that good work was done in suppressing the gipsy moth during 1910 and 1911. The town is located a little out of the line of wind dispersion, and this, coupled with careful hand work, has evidently resulted in the satisfactory condition which has been reported.

The results in Bennington, N. H., a town which is located on high land, where 21 per cent of the trees are oak, point strongly to the fact that the woodlands do not become infested rapidly when they are located in a region unfavorable for larval spread by the wind. Although about 5 square miles were examined in this town, no woodland infestation was found; and when it is remembered that this area is less than 10 miles from towns which were found infested in 1908 and 1909, the evidence is further strengthened. The danger of artificial spread of gipsy-moth caterpillars on vehicles is probably less in this town than in any of the towns where woodland areas have been scouted.

The scouting in Gardner and Wareham, Mass., was handicapped by the fact that the woodland growth was not satisfactory for the

establishment of the species, although the selection of areas containing the most deciduous growth in both towns aided in securing more satisfactory data.

Wareham was found infested in 1905, and if the town had been located along the line of prevailing winds at the time the gipsy-moth caterpillars were in the first stage, the woodlands would probably be as badly infested as those in towns an equal distance north or north-east of the original infested area. This is not the case, however, which indicates in itself that unfavorable food and practical immunity from winds favorable for spread have worked to the advantage of this town.

The same statement can be made of both Gardner and Grafton, which were found infested in the winter of 1907-8. It is true that there are a considerable number of small roadside and orchard infestations in these towns, particularly in Grafton, but travel is heavy during the early summer and an excellent opportunity is offered for the spread of the larvæ on vehicles and automobiles. If wind spread were not a prime factor in distributing the gipsy moth, the woodland in Grafton should be more heavily infested than the wooded area examined in Milton, N. H., because the latter town is much farther from the original center of infestation, and was first found infested a year later.

It is practically impossible to explain the origin of many separate infestations; but taking the woodland areas examined and studying them in relation to each other and in relation to the badly infested area, it is evident that the theory already given concerning wind spread is confirmed.

It is surprising, when all the facts are considered, that so much good work has been done in controlling the gipsy moth in many of the infested towns. Large numbers of cases are on record where all the infestations in a town have practically been cleared of this insect in a single year; but, owing to general wind spread, as many and usually more colonies have been found in other parts of the same town the next year. This is one of the discouraging features of the work and renders it extremely difficult to control the insect in towns which are most subject to natural spread by the wind. It is obvious that if this is to be brought about, bad colonies must be subdued, particularly those which are nearest the outside border of infestation, because, as has already been pointed out, the farther the larvæ are carried by the wind the less the chance becomes for them to establish the species, owing to their wide separation from other specimens and the limited opportunity of their finding suitable food for full development.

EFFECT OF WIND SPREAD ON THE PROBLEM OF GIPSY-MOTH CONTROL.

The fact that gipsy-moth caterpillars are spread chiefly by wind during the time they are in the first stage and that for this reason the present spread of the insect is toward the northeast, northwest, and north has been sufficiently demonstrated. Another factor which enters into the problem to a greater or less extent, and which has an important bearing on the spread of young caterpillars by air currents, is the altitude of the woodland in the various towns.

Whether high altitudes are more likely to become infested in this way than low areas it is difficult to state, but there can be no question in regard to the difference in temperature of winds after having passed over an area of high land. For example, the cold winds which sweep down the New England coast from the northeast and east are not accompanied by as low temperature, nor are such winds as cold or penetrating in the central part of Massachusetts as they are along the seacoast. As high winds must be accompanied by high temperature in order to bring about the spread of young caterpillars, it can be stated that after the territory on the west side of the watershed in Massachusetts and New Hampshire becomes infested to such a degree that large areas are defoliated, the spread of the young caterpillars by wind will be more far-reaching and more rapid than it has been at any period since the moth first became established. It is indeed a fortunate thing that the gipsy moth first found lodgment on the North Atlantic seaboard, on account of the various elements which have worked together to restrict its spread. If the insect had first escaped in central Massachusetts, in Connecticut, or in New York State there would have been ample opportunity for spread in all directions, and it would have been difficult to restrict it to anything like the area which it now occupies.

SUMMARY.

The gipsy moth is spread by local and long-distance means.

Local spread may be due to the transportation of caterpillars or egg clusters on carriages or wagons that move for only a short distance outside the infested territory. The egg clusters may be carried on driftwood which floats down rivers during the spring.

Long-distance spread may be due to the shipment of egg clusters on lumber products, nursery stock, or boxes from the infested territory to any points where such goods are unloaded. Caterpillars may be, and often are, carried long distances on automobiles or trolley cars, and cases are on record where colonies have been established in this way.

By far the greatest dispersion is due to the fact that first-stage caterpillars are blown by the wind. A glance at the present infested territory shows that dispersion has been along the line of the prevailing winds immediately following the hatching of the caterpillars. One condition favoring wind spread is the presence of large woodland colonies which are overpopulated with caterpillars. This stimulates activity on the part of the insects in search of food and affords opportunities for them to be carried away by the wind. High temperature increases the activity of the caterpillars, and this tends to increase the chances of their being blown away. Weather records for the past 10 years show that the prevailing winds during April and May, when the temperature is high enough to make the caterpillars sufficiently active, and when the wind is strong enough to blow them for any great distance, are for the most part from the south and southwest.

The character of the food has a very important bearing on the dispersion of this insect, because unless caterpillars that are blown by the wind are able to find lodgment on favorable plants they will not survive, and there will be no opportunity for the species to become established. If a number of first-stage caterpillars were dropped by the wind into a forest of solid pine they would not be able to establish a colony, because these small caterpillars can not survive on pine foliage. There are other trees, particularly conifers, which are equally immune from injury by the first-stage caterpillars, and upon which they are not able to develop. This shows that large blocks of unfavorable food plants will not only prevent the establishment of the insect, but that such woodland will require no treatment whatever, provided it is isolated by removing the favored food plants near by.

RECOMMENDATIONS.

As a result of the experiments which have been conducted and a study of the data which have been secured, the following recommendations are made, as these have a practical bearing on the gipsy-moth problem:

(1) National legislation should be enacted to provide for the inspection of lumber products or other material which is likely to carry the gipsy moth from the territory which is now infested to uninfested regions. This is particularly important and is distinctly of national concern, because goods of this sort are often shipped to far distant points in the United States, and without careful scrutiny excellent opportunities are offered for establishing new colonies remote from the area in New England which is now infested.

(2) Inasmuch as certain coniferous trees, if grown in solid stands, will not furnish favorable food for small gipsy-moth caterpillars that might be distributed by wind spread, and as some of our decidu-

ous trees will probably furnish similar unfavorable food conditions, it seems very important to determine by careful experiment the susceptibility to gipsy-moth attack of the various species of native trees in New England forests and to test different methods of thinning woodlands in order to reduce the infestation by furnishing unfavorable food, and by so doing to prevent the area thus treated from becoming so badly infested as to enable caterpillars to be spread from it by the wind. These experiments are now under way.

(3) The experiments conducted indicate that little spread by the wind will result unless badly infested areas exist. Inasmuch as the principal spread over a wide area is due to the wind, more attention should be paid to the proper handling of bad woodland colonies along the lines already indicated, in order to prevent widespread distribution. From the experiments conducted, and from the data examined, and as a result of interviews and conversation with various officials and parties interested in moth work, it appears that the spread of the gipsy moth at the present time by automobiles or other traffic is far less serious than heretofore. Already a large mileage of trees along trunk roads has been thinned and protected, so that the danger has been largely reduced in this way. Special attention has been given to many roads leading to and from summer resorts or camping places where automobile traffic is heavy during the summer, and as a result of this work and of the scouting which has been carried on in the outlying territory, which included an examination of the trees along many of the trunk roads in uninfested sections of the State as well as an inspection of places, such as hotel grounds, where touring parties would be likely to stop, it has become quite evident that in the last year or so the danger of infestation by means of automobiles has been greatly reduced. This would indicate the desirability of reducing the thinning operations along roadways, except on those where the automobile traffic is the heaviest during May and June.

(4) The work which has to do with the determination of the limits of spread of the insect, and which is known as the scouting, is of great importance. This is being carried on in the outside infested towns and in those adjoining, and too much stress can not be laid on its thorough prosecution. The men actively engaged in it should be instructed thoroughly in regard to the best methods of thinning woodland in order to control the moth, so that practical advice can be given to the owners of forest land to stimulate them to take proper measures for protecting their property before the infestation becomes serious enough to cause severe injury.





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